Upper Assiniboine River Basin Study

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101-01928

Upper Assiniboine River Basin Study

Appendix D

Water Quality Committee Report

August 2000

Executive Summary

The Water Quality Committee assumed the responsibility of meeting the Study objectives of assessing the quality of the Upper Assiniboine River Basin's water resources and identifying the effects of various activities on water quality. With input from Basin residents, the Committee identified water quality concerns. It then reviewed existing information for those issues. They were:

- The effects of agricultural drainage on water quality;
- Nutrient enrichment of water bodies from municipal effluent;
- Nutrient enrichment from livestock access to watercourses;
- Trends in water quality for the Basin; and
- The protection of groundwater from contamination.

Some of the impacts of agricultural land drainage on water quality include nutrient loading, pesticide contamination, heavy metal contamination, erosion and sedimentation. As well, water quality benefits accrued by wetland retention are lost when wetlands are drained. Ammonia nitrogen, nitrates and nitrites can negatively impact water quality of receiving water bodies when transported by a drainage system. Particulate phosphorous may be transported downstream to receiving water bodies via agricultural drainage when soil particles erode and are carried with the water flow.

Effective wastewater treatment involves proper planning, design, construction, operation, monitoring. The Town of Roblin in Manitoba has designed a comprehensive program for the treatment and management of its effluent and reduction of nutrients being discharged into the local watershed. The project consists of constructed wetlands and a hybrid poplar wood lot in addition to the existing irrigation system. Other towns are observing the Roblin experience and considering the possibilities open to them through the proper management of their treated effluent.

Various demonstration projects conducted in the Study area showed that improvement to riparian areas through alternative pasturing, livestock watering systems, and properly located and managed winter feeding sites are effective in maintaining water quality. There can be a benefit in increased awareness of the value of manure as a resource rather than a waste. In addition, manure management practices should be improved.

There are other key points that should be targeted by and for the agricultural industry in general with respect to improving water quality. These include the proper handling and application of farm chemicals and pesticides; appropriate methods and locations for cleaning sprayers and empty containers; use of container disposal sites; testing for the effects from hazardous substances in landfills, container collection sites, and discontinued bulk fuel depots and gas stations; and, development of Best Management Practices for annual cropping.

Groundwater plays an important part in the everyday life of the majority of the population in the Basin. Many of the major aquifers in this area are vulnerable to contamination by surface activities. Even deeper formations, that are normally considered safe, are susceptible to contamination if precautions are not taken. Old wells are a major concern if they are not properly abandoned, as they can be a major factor in allowing contaminants to enter the water bearing formation. Proper decommissioning of abandoned wells; proper maintenance of existing wells; and proper siting and construction of new wells are all factors to be considered in protecting water quality.

The management of groundwater throughout the area is the responsibility of the provincial governments and is generally shared between a number of agencies within each province. While each agency compiles large amounts of data regarding the different aspects of groundwater quality and quantity each year, there is little integrated database management. As a result, much of the information regarding ground water availability and quality is lacking continuity and can be difficult to obtain.

Although some regulations are in place for protection of groundwater, more work must be carried out to limit the occurrences of contamination and their effects. Monitoring of groundwater, particularly in the most sensitive areas, must be implemented and carried out in order to track the changes occurring to the water formations. Without long-term monitoring, it will be impossible to adequately protect the Basins's groundwater in the future since changes will not be detected until contamination is widespread.

A review of the available data for several water bodies in the Upper Assiniboine River Basin indicates that in general the water quality is suitable for its expected uses. There are areas where limitations to such uses as irrigation are evident. It is important to note that in some cases the assessment is based on a limited quantity of data. Additional monitoring would be required to update the water quality conditions at those locations. The Prairie Provinces Water Board (PPWB) sampling site on the Assiniboine River near Kamsack provides an ongoing measure of water quality trends in the upper reaches of the Basin and provides the only current data source. Trend analysis results for the Assiniboine River were encouraging. There were no constituents that showed a significant, long-term increasing trend. However, dissolved oxygen, total phosphorous and dissolved manganese did show exceedances to the PPWB water quality objectives and may affect downstream uses.

Recommendations provided in this report relate to monitoring requirements, agricultural practices, water resource protection and information and education. Surface and ground water monitoring should be improved to determine current conditions. Increased testing will highlight areas of concern and long-term trends. Best management practices for agriculture and other industries throughout the Basin need to be developed emphasizing improved riparian areas and surface and ground water protection. Water quality impacts should be considered in evaluation of drainage projects. Maintenance of existing wetlands should be encouraged to reduce nutrient loading and sediments in receiving waters. Groundwater protection measures include proper disposal of chemical containers, proper well design, maintenance and abandonment. The long-term impacts of municipal wastewater releases need to be assessed.

Acknowledgements

The Water Quality Committee would like to thank Dillon Consulting Limited for their work on the literature review and the preparation of the document "Upper Assiniboine River Basin Water Quality". In particular the committee would like to thank Nicholas Barnes, the project manager.

The Water Quality Committee wishes to acknowledge the following for their technical assistance and commitment of time and effort to ensure that the off-stream livestock watering demonstration project would proceed: PK Herefords, Ducks Unlimited, District 19 ADD Board, Saskatchewan Agriculture and Food, and Saskatchewan Environment and Resource Management.

The Committee would like to acknowledge the partners of the Whitesand River Watershed Enhancement Project which included co-operators PK Herefords, Tom Lamont, Carey Weinbender, Ward Manahan, Ivan Olynyk, Brian Berrns, James Sharpe, Al Claiter and Duane Thompson; Prairie Farm Rehabilitation Administration; Saskatchewan Wetland Conservation Corporation; and Saskatchewan Agriculture and Food.

The Water Quality Committee would like to thank the Town of Roblin for agreeing to use its alternative effluent management system as a demonstration project for the Upper Assiniboine River Basin Study.

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Many thanks are also extended to the GIS Committee for the development and generation of the maps for the Dillon Consulting Limited report and Water Quality Committee's report.

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- Saskatchewan Agriculture and Food

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1 Introduction

The governments of Saskatchewan, Manitoba and Canada agreed to undertake a comprehensive water management study of the Upper Assiniboine River Basin in eastern Saskatchewan and western Manitoba. The Study area includes the entire Basin in Saskatchewan and Manitoba north of the Qu'Appelle River. This portion of the Basin has a drainage area of 21,000 km^2 of which 79 percent is in Saskatchewan (Figure 1.1). The Study was a response to public demand for the resolution of the diverse and persistent water management issues in the Basin. Water related issues include: conflict between agricultural drainage interests and downstream flooding, uncertainty over water supplies, concerns over the disappearance of wetland and wildlife habitat, and complaints linked to the quality of the Basin's water bodies and aquifers. The purpose of the Study was to develop a water management framework to guide future water management in the Basin to resolve these issues. A complete overview of the Study is contained in the main Study report.

The Study was initiated by an Agreement among the governments of Saskatchewan (represented by the Saskatchewan Water Corporation (Sask Water)), Manitoba (represented by Manitoba Conservation) and Canada (represented by Environment Canada) in October 1996. Many other private citizens, consultants, and agencies (including the Prairie Farm Rehabilitation Administration, Ducks Unlimited Canada, Manitoba Agriculture and Food, Manitoba Industry and Trade, Manitoba Intergovernmental Affairs, Saskatchewan Agriculture and Food, Saskatchewan Environment and Resource Management, Saskatchewan Wetlands Conservation Corporation, and Saskatchewan Municipal Affairs, Culture and Housing) contributed to this Study. Study work was undertaken by five technical committees, a strategy committee and supported by a communications committee. Public involvement was a vital component of the Study and was facilitated through six local watershed committees.

This committee report discusses the water quality knowledge gained over the course of the Upper Assiniboine River Basin Study.

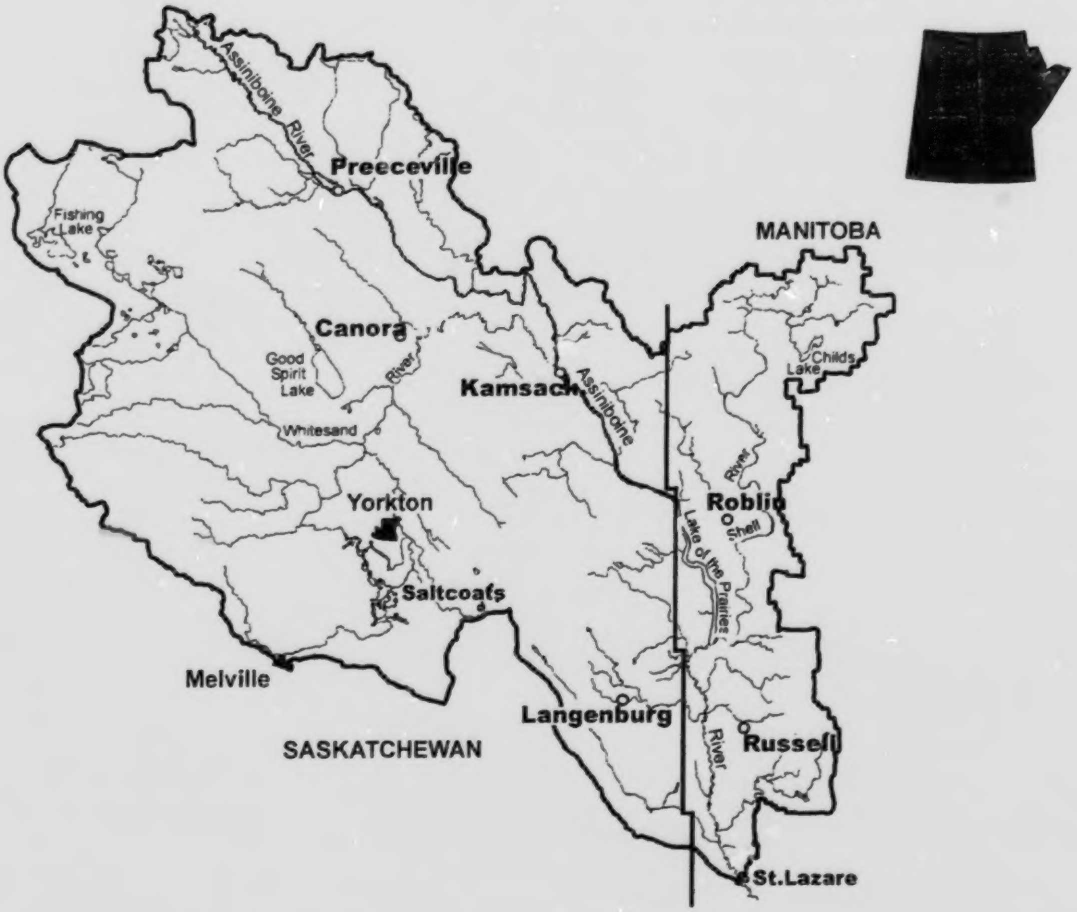
1.1 Water Quality Committee

The Water Quality Committee was comprised of personnel with a background in water quality representing Saskatchewan, Manitoba and Canada. The committee identified water quality concerns within the Basin, reviewed existing information for those identified issues, formed an information program, and advanced recommendations to be used in the development of a water management framework.

1.2 Objectives

The objectives of the Water Quality Committee were to assess the quality of the Basin's water resources by gathering and reviewing the existing water quality information. The committee also identified and reviewed the effects of various activities within the Basin on water quality.

Figure 1.1
Upper Assiniboine River Basin Study Location Plan


Assiniboine River
Preeceville
Fishing Lake
MANITOBA
Canora
Good Spirit Lake
River
Kamsack
Assiniboine
Childs Lake
Whitesand
Yorkton
River
Roblin
Shell
Lake of the Prairies
Saltcoats
Melville
Langenburg
River
Russell
SASKATCHEWAN
St.Lazare

Water Quality concerns raised at a series of open houses in November 1996 by local residents provided the primary focus for the Water Quality Committee's activities. The issues raised were compiled and prioritized and provided the basis of the committee's terms of reference (Appendix I). The water quality issues identified and addressed by the committee were:

- The effects of agricultural drainage on water quality;
- Nutrient enrichment of water bodies from municipal effluent;
- Nutrient enrichment from livestock access to watercourses;
- Trends in water quality for the Basin; and
- The protection of groundwater from contamination.

1.3 Scope of Work

To address the identified issues the Water Quality Committee commissioned Dillon Consulting Limited of Winnipeg to conduct a literature review on the effect of these activities within the Basin on water quality. The specific objectives of the Study were to review the effects of agricultural drainage, livestock and range management practices, and municipal lagoon releases on surface and ground water quality. In addition, groundwater protection information and related education materials were to be compiled. The literature review was based primarily on existing information directly related to the Upper Assiniboine River Basin, or where information was not available, the Canadian Prairies or other specific regions. The consultant's report was completed in November 1998 and is contained in Appendix II. The information compiled in the literature review was then used by the Water Quality Committee as the basis for the development of a public information brochure.

Surface water quality monitoring of the main water bodies in the Basin has been conducted but only to a limited extent. Samples have been collected and analyzed from the Assiniboine River, the Whitesand River, Fishing Lake, Good Spirit Lake, Lake of the Prairies, Shell River and Big Boggy Creek. The Committee reviewed the existing water quality data collected from these water bodies to examine whether the water is suitable for most expected uses when compared to the current Water Quality Objectives.

The most comprehensive water quality information for the Basin is from the Prairie Provinces Water Board monitoring station near Kamsack. Monitoring at this station has been conducted on a monthly basis since 1974. Water quality data collected by the Prairie Provinces Water Board for the period 1981 to 1997 were examined to assess the long-term trends in water quality.

Livestock are an integral part of the agricultural activity within the Upper Assiniboine River Basin. Management practices associated with all types of livestock activities do have an impact on groundwater and surface water quality. Livestock watering in streams and rivers has the potential to degrade riparian areas, and increase nutrients and pathogens. During the course of this study, the Water Quality Committee participated in several livestock demonstration projects within the Basin. In the summer of 1998 and 1999, an off stream watering demonstration project was conducted on the Whitesand River south of Canora.

In 1999, the Whitesand River watershed enhancement projects were also undertaken with six co-operators with cattle near the Whitesand River or a tributary of the river. Numerous activities were undertaken by the project co-operators throughout the spring, summer, and fall of 1999. These activities included establishment of vegetative buffer strips, conversion of crop land to forages, fence construction, off stream watering site development, berm construction, improvement of low-level crossings, rotational grazing management planning, and the relocation of winter feeding sites.

Cropping, field runoff, and drainage activities can all impact water quality. The movement of water across cultivated fields can transport nutrients, sediment, and pesticides to surface and ground water supplies. The committee examined the roles of best management practices and the ability of riparian buffer areas to minimize the impacts on water quality.

Throughout the Basin there are 32 towns that operate multi-celled lagoons as part of their wastewater treatment system. Each province has discharge objectives and regulations that control the construction, operation, and pollution control mechanisms for lagoons. Despite these objectives and regulations, lagoon systems do have the potential to impact receiving waters with the susceptibility being dependant on the location, soil type, and timing of the release. The committee reviewed the impact of the release of effluent from lagoons on receiving water bodies. It also examined alternative management systems for the disposal of treated wastewater effluent such as the combined use of a traditional lagoon system and constructed wetlands implemented by one town within the Basin.

Groundwater is an important water resource within the Basin and used as the major source of potable water for numerous cities, towns, villages, and individuals throughout the region. The committee examined the various sources of groundwater contamination and the methods for protecting groundwater supplies including proper well siting and construction, protection from potential contaminants in the recharge area, adopting beneficial management practices to reduce non-point contamination from agricultural sources, monitoring, and the need to properly decommission and seal unused or abandoned wells.

2 Surface Water Quality

2.1 Introduction

Surface water is one of the most important resources in the Upper Assiniboine River Basin. Major uses of surface water in this area include recreation, potable water supplies, use by aquatic life, and agricultural uses such as irrigation, and livestock watering.

Agriculture is the primary economic activity within the Upper Assiniboine River Basin. Activities such as increased drainage of sloughs, runoff from intensive livestock operations, and increased use of fertilizer and chemicals all have the potential to affect water quality in the area. Other activities that may alter surface water quality within the Basin include: discharges from municipal sewage lagoons; runoff from landfills and hazardous substance storage sites, such as chemical collection depots; and indiscriminate disposal of wastes such as used oil.

In general, any substance that may enter a body of water is deemed to be a potential pollutant if it adversely affects water quality for any specific use. The primary factors that influence water quality are the nature and total volume of the polluting effluent. However, the resulting quality of water also depends upon the quality of the receiving water, its assimilative capacity, the rate of water flow, and the rate of chemical and biological changes within the system.

Water quality is periodically monitored by taking samples which are analysed to identify specific dissolved and suspended substances. Figure 2.1 identifies where provincial water quality sampling stations have been located in the Basin.

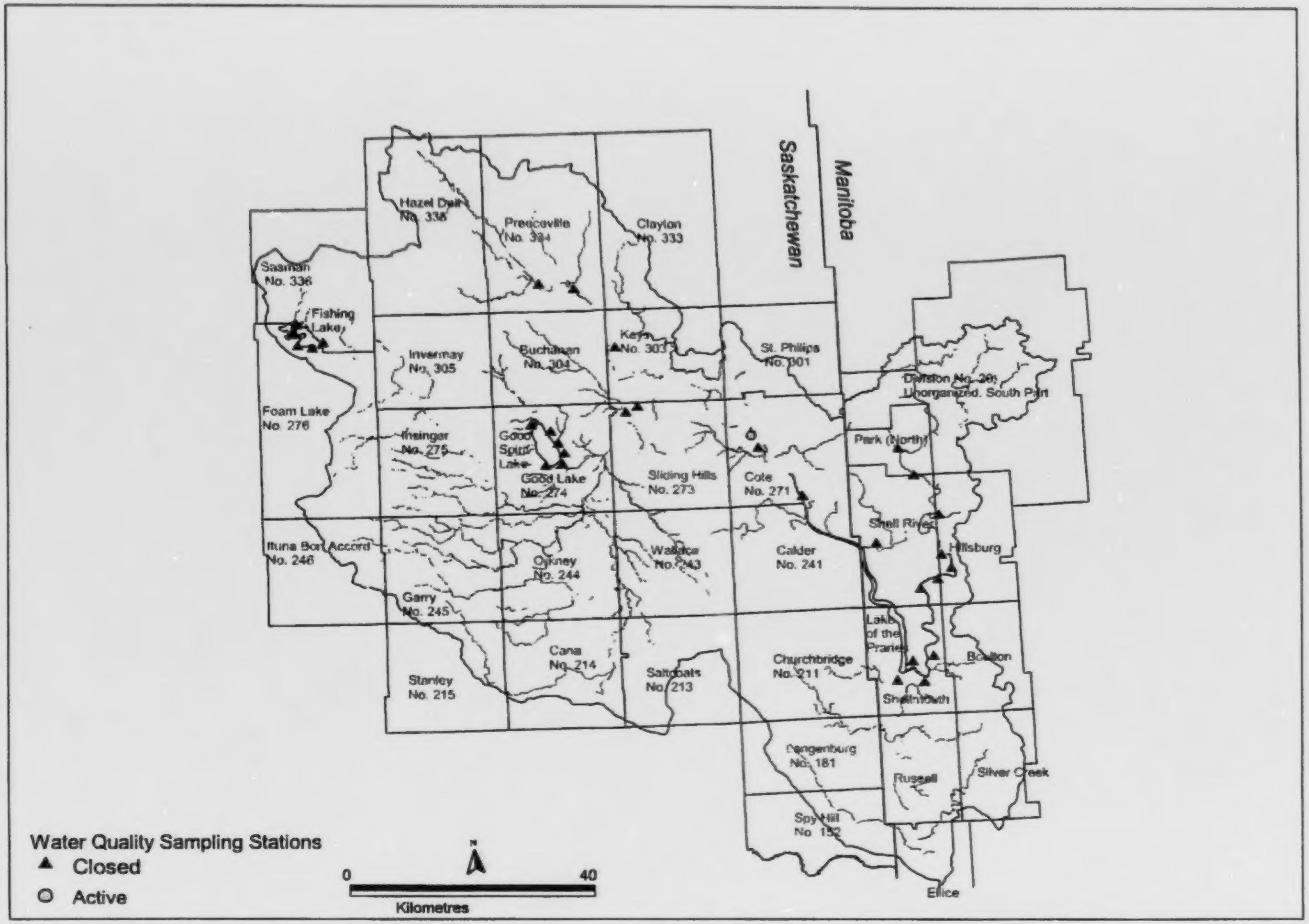
2.2 Legislation

2.2.1 Saskatchewan

The Province of Saskatchewan has various acts, policies, regulations, and guidelines to conserve water and to protect, maintain, and improve its quality for the protection of public health, as well as for the following purposes:

- Preservation and protection of water supplies;
- Sustainable development of agriculture and other economic activities;
- Preservation of aesthetic values;
- Preservation of fish and wildlife; and
- Municipal and domestic water supplies.

Figure 2.1
Locations of Water Quality Monitoring Stations


Saskatchewan
Manitoba
Hazel Dell No. 335
Preeceville No. 334
Clayton No. 333
Sasman No. 336
Fishing Lake
Invermay No. 305
Buchanan No. 304
Keys No. 303
St. Philips No. 301
Division No. 20, Unorganized, South Part
Foam Lake No. 276
Insinger No. 275
Good Spirit Lake
Good Lake No. 274
Sliding Hills No. 273
Cote No. 271
Park (North)
Shell River
Hillsburg
Ituna Bon Accord No. 246
Orkney No. 244
Wallace No. 243
Calder No. 241
Garry No. 245
Lakes of the Prairies
Boulton
Stanley No. 215
Cana No. 214
Saltcoats No. 213
Churchbridge No. 211
Shellmouth
Langenburg No. 181
Russell
Silver Creek
Spy Hill No. 152
Ellice
Water Quality Sampling Stations
▲ Closed
○ Active
0
40
Kilometres
N

2.2.1.1 Surface Water Quality Objectives

Saskatchewan has established specific *Surface Water Quality Objectives* (Saskatchewan Environment and Resource Management, 1997) which are used to assess surface waters and evaluate their suitability for various uses. Major parameters for assessing the suitability of water for its various uses in the Basin include: bacteria (total and fecal coliforms), total dissolved solids, major ions, nutrients (nitrogen and phosphorous), dissolved oxygen, pesticides, pH, mercury, etc. For example, fecal coliform counts in excess of 200 per 100 millilitres (mL) of sample would indicate that the water is not acceptable for non-contact recreation (e.g., boating, fishing). Total dissolved solids greater than 1000 milligrams per litre (mg/L) may not be tolerated by all types of livestock. Similarly, levels of sodium and total dissolved solids greater than 100 and 700 mg/L respectively, may make the water unsuitable for irrigation depending on the soil irrigated and crop grown.

In terms of water quality, Table 2.1 provides a brief analysis of the suitability (by water use) of the major water bodies within the Basin.

2.2.1.2 Water Pollution Control and Waterworks Regulations

Saskatchewan's *Water Pollution Control and Waterworks Regulations* regulate all the municipal waterworks exceeding a capacity of 18 cubic metres per day. Waterworks of less than 18 cubic metres per day (e.g., private wells, municipal wells) are regulated by Saskatchewan Health. Regulated waterworks are permitted by Saskatchewan Environment and Resource Management (SERM), and some permit requirements include:

- daily testing for total and free chlorine; and
- sample submissions to the provincial lab for testing of bacteria, nitrates, sulphates, arsenic, iron, selenium, pesticides, trihalomethanes, cyanide, mercury, benzene, etc.

2.2.1.3 Other Regulations/Guidelines

In addition to the provincial *Surface Water Quality Objectives* and *Water Pollution Control and Waterworks Regulations,* some other acts, regulations, and guidelines that are currently in place in Saskatchewan to help protect water quality, include:

- *The Environmental Management and Protection Act*;
- *The Hazardous Substances and Waste Dangerous Goods Regulations*;
- *The Drainage Control Regulations*; and
- *The Agricultural Operations Act.*

2.2.2 Manitoba

The following acts, regulations and objectives govern water quality in Manitoba:

- *The Manitoba Environment Act*;
- *The Livestock Manure and Mortalities Management Regulation*;
- *The Manitoba Dangerous Goods Handling and Transportation Act;*
- The *Manitoba Surface Water Quality Objectives;*
- *The Protection of Water Sources Regulations* under *The Public Health Act*; and
- The fish consumption guidelines for Lake of the Prairies based upon mercury concentrations.

Table 2.1

Suitability of Some Water Bodies in the Upper Assiniboine River Basin, for Various Uses*

Water Bodies	Recreation	Irrigation	Aquatic Life	Livestock Watering
Good Spirit Lake (1993 - 1998)	✓	(✓)	✓	✓
Fishing Lake (1993 - 1998)	✓	×	✓	×
Whitesand River (1980 - 1998)	✓	(✓)	✓	✓
Assiniboine River (1980 - 1998)	✓	(✓)	✓	✓
Shell River (1991-1993)	✓	✓	✓	✓
Big Boggy Creek (1991-1993)	✓	✓	✓	✓
Lake of the Prairies (1991-1993)	✓	✓	✓	✓

* Using data from water quality monitoring stations upstream of known waste water discharges to represent ambient conditions.

✓ Suitable

(✓) Suitable with some limitations based on soil irrigated and crop grown.

X Not Suitable

2.3 Water Quality in Saskatchewan

Saskatchewan Environment and Resource Management (SERM) has conducted some water quality monitoring on major water bodies in the Basin such as the Assiniboine River, Whitesand River, Good Spirit Lake, and Fishing Lake. The location of sampling stations where SERM monitored water quality is shown on Table 2.2 and Figure 2.1. The following section provides a brief overview of the water quality for these water bodies based on available data. The water quality will also be compared to Saskatchewan's *Surface Water Quality Objectives* (SERM, 1997) where applicable. All water quality data are reported in milligrams per litre (mg/L) except for fecal coliform bacteria which are measured in organisms per 100 millilitres of water (organisms /100 mL).

2.3.1 Assiniboine River

The Assiniboine River originates northwest of the Town of Preeceville, Saskatchewan, and flows in a southeasterly direction before entering Manitoba at Lake of the Prairies (also known as Shellmouth Reservoir). The Saskatchewan portion of the Assiniboine River is classified as an intermittent stream (Lane and Sykes, 1982), since annual peak flows are highly variable and flow decreases very rapidly after spring runoff. In dry years, the flow may decrease to zero during late summer and autumn.

Table 2.2
Location of Water Quality Sampling Stations

Upper Assiniboine River Basin
Major Waterbodies and Location of Sampling Stations

Waterbody	**Sampling Station**	**Latitude**	**Longitude**	**Legal Land Description**
Assiniboine River	Nr. Kamsack WTP	51Deg34'10"	101Deg55'15"	SW3-30-32-W1
	No. 5 Hwy.	51Deg33'45"	101Deg54'40"	NW34-29-32-W1
	No. 8 Hwy.	51Deg32'0"	101Deg53'15"	NW23-29-32-W1
	No. 357 Hwy.	51Deg24'25"	101Deg45'0"	SE11-28-31-W1
	No.47 Hwy.	52Deg57'05"	101Deg40'05"	NE29-34-5-W2
	Sturgis Weir	51Deg56'15"	101Deg32'50"	NW20-34-4-W2
	No. 9 Hwy.	51Deg47'35"	101Deg24'25"	NW32-32-3-W2
Whitesand River	Opp. Canora WTP	51Deg38'12"	102Deg22'22"	NE28-30-3-W2
	1 mile E. of Canora	51Deg38'17"	102Deg20'31"	SE34-30-3-W2
	6 miles E. of Canora	51Deg39'28"	102Deg16'22"	SE1-31-3-W2
Good Spirit Lake	North End	51Deg35'0"	102Deg41'25"	SW8-30-5-W2
	Canora Beach	51Deg35'35"	102Deg40'15"	NE17-30-5-W2
	Mid Lake	51Deg33'25"	102Deg40'0"	NE33-29-5-W2
	Burgis Beach	51Deg32'55"	102Deg37'35"	NE27-29-5-W2
	South End	51Deg31'45"	102Deg38'50"	NE21-29-5-W2
	Prov. Park Beach	51Deg30'30"	102Deg39'45"	SW16-29-5-W2
Fishing Lake	Buckhorn Bay	51Deg50'50"	103Deg32'50"	NE19-33-11-W2
	Saskin Beach	51Deg50'40"	103Deg31'15"	NE20-33-11-W2
	Southwest Bay	51Deg49'20"	103Deg31'50"	NW8-33-11-W2
	Leslie Beach	51Deg48'55"	103Deg33'25"	SW7-33-11-W2
	Southeast Bay	51Deg48'55"	103Deg29'20"	SW10-33-11-W2

Water quality monitoring on the Assiniboine River has been carried out sporadically over the years. Table 2.3 (A to D) shows minimum, maximum and mean (average) values for the most significant water quality parameters as measured at seven sites along the river during the period 1980 to 1998. The sampling frequency varied considerably from one station to another, with the station at No. 9 Highway sampled once, while the site at No. 5 Highway was sampled up to 40 times. This confirms that data for certain sites may be limited, and in cases where monitoring has been discontinued for some time the results may be dated. Therefore, it is important that these data be interpreted with caution and especially with reference to the water flows present at the time of sampling. Also, some stations are located in the municipal wastewater discharge mixing zones which may not represent ambient conditions in the river. Water quality at these stations is generally affected during the periods of municipal discharge.

Table 2.3
Water Quality Results for the Assiniboine River Versus Saskatchewan Surface Water Quality Objectives* for Irrigation, Livestock Watering, and Non-contact Recreation
1980 to 1998

(A)

Fecal Coliform Counts				
Station	**No. of Samples**	**Min**	**Max**	**Avg**
Sturgis Weir	11	2	600	90
No. 47 Hwy	8	1	40	23
No. 9 Hwy	5	4	40	23
Nr. Kamsack WTP	7	10	23	12
No. 5 Hwy	37	2	150	30
No. 8 Hwy	12	6	590	79
No. 357 Hwy	8	2	10	8

** Irrigation=100/100 mL; Non-Contact Recreation=1000/100 mL*

(B)

Nutrients:	**Total Kjeldahl Nitrogen***				**Phosphorous***			
Station	**No. of Samples**	**Min**	**Max**	**Avg**	**No. of Samples**	**Min**	**Max**	**Avg**
Sturgis Weir	13	1.0	6.6	2.5	13	0.06	0.50	0.21
No. 47 Hwy	10	1.1	6.9	2.2	10	0.06	1.17	0.32
No. 9 Hwy	5	0.7	1.7	1.0	5	0.05	0.14	0.09
Nr. Kamsack WTP	7	0.4	2.8	1.3	10	0.07	0.52	0.15
No. 5 Hwy	40	0.1	15.0	2.8	40	0.02	1.25	0.29
No. 8 Hwy	14	0.2	4.7	2.2	14	0.08	0.75	0.32
No. 357 Hwy	---	---	---	---	11	0.05	0.85	0.32

** no set objectives*

(C)

	Sulphate				**Total Dissolved Solids (calculated)**			
Station	**No. of Samples**	**Min**	**Max**	**Avg**	**No. of Samples**	**Min**	**Max**	**Avg**
Sturgis Weir	10	51.0	170.0	98.3	10	241	851	597
No. 47 Hwy	8	48.0	112.0	81.1	8	218	782	532
No. 9 Hwy	1	96.0	96.0	96.0	1	749	749	749
Nr. Kamsack WTP	11	64.0	208.0	148.0	11	299	1371	759
No. 5 Hwy	34	59.0	268.0	155.0	33	261	996	655
No. 8 Hwy	11	112.0	395.0	174.0	11	453	1362	747
No. 357 Hwy	11	108.0	173.0	147.0	11	413	807	591
** Livestock=1000 mg/L*					** Irrigation=700 mg/L; Livestock=1000 mg/L*			

(D)

	Chloride				**Sodium, dissolved**			
Station	**No. of Samples**	**Min**	**Max**	**Avg**	**No. of Samples**	**Min**	**Max**	**Avg**
Sturgis Weir	13	2.0	75.0	13.5	10	1.0	32.0	19.2
No. 47 Hwy	10	2.0	26.0	6.3	8	1.0	36.0	16.8
No. 9 Hwy	5	4.0	14.0	8.0	1	22.0	22.0	22.0
Nr. Kamsack WTP	11	4.0	26.0	8.8	11	6.0	54.0	27.1
No. 5 Hwy	40	2.0	350.0	30.3	34	16.0	96.0	41.1
No. 8 Hwy	14	14.0	110.0	37.0	11	36.0	147.0	55.7
No. 357 Hwy	10	15.0	37.0	22.6	11	27.0	47.0	37.7
** Irrigation=100 mg/L*					** Irrigation=100 mg/L*			

2.3.1.1 Microbiological Water Quality

The provincial microbiological water quality objectives are based on counts of total and fecal coliform bacteria. Since fecal coliforms are naturally abundant in the lower intestine of humans and other warm-blooded animals, and are rare or absent in unpolluted waters, their presence serves as a reliable indication of sewage or fecal contamination in water.

Table 2.3 (A) shows the fecal coliform bacteria counts for the Assiniboine River compared to the provincial surface water quality objectives for irrigation and non-contact recreation. It is generally recognized that very little, if any, contact recreation (swimming, water skiing) occurs in the river.

Based on the mean fecal coliform counts, the Assiniboine River met the surface water quality objectives for irrigation and non-contact recreation during the sampling period. The maximum one-time count at the Sturgis Weir site of 600 organisms per 100mL occurred in April, 1985 during a municipal wastewater discharge from the Town of Preeceville. Similarly, the maximum count at No. 8 Highway (590 organisms/100mL) occurred during a discharge from the Town of Kamsack in April, 1991. A 1991 study on the impacts of the Kamsack discharge confirmed elevated levels of bacteria below the discharge point, but the values quickly returned to ambient (background) levels within a short distance downstream (as shown by the data for No. 357 Highway), and the overall impact of the effluent on the river water quality was minimal. Although the surface water quality objective for irrigation was exceeded on these two occasions, there is little likelihood that the water would be used for irrigation at that time of year.

2.3.1.2 Nutrients

Table 2.3 (B) shows the concentration of total nitrogen and total phosphorus in the Assiniboine River for the period 1980 to 1998. Mean total nitrogen concentrations ranged from 1.0 to 2.8 mg/L with a maximum one-time value of 15.0 mg/L at No. 5 Highway. Mean total phosphorus ranged from 0.09 to 0.32 mg/L with a maximum of 1.24 mg/L. Elevated nutrient levels occur naturally throughout the Basin but this situation may be exacerbated by municipal wastewater discharges. The levels normally returned to background concentrations within a short distance downstream of the discharge points.

In Saskatchewan, nutrient levels in surface waterbodies are naturally high due to the nutrient-rich soils found throughout the province. As such, there are no specific water quality objectives for these parameters. The Canadian Council of Ministers of the Environment (CCME) and various provinces, including Saskatchewan and Manitoba, are presently in the process of developing water quality objectives for nutrients. In the meantime, the provinces continues to use general objectives that state nutrient concentrations should not be increased from natural levels such that nuisance growths of algae or aquatic weeds result.

2.3.1.3 Water Chemistry

The sum of the dissolved ions (mineral salts) in water is closely related to water salinity and is usually expressed as total dissolved solids (TDS). Salinity of the water is most important with respect to various agricultural uses such as irrigation or livestock watering, and is determined by the types of rock or soil in the watershed and by the amount of evaporation relative to precipitation. The Saskatchewan surface water quality objectives specify that the level of TDS in water should be less than 700 mg/L when used for irrigation, and less than 1000 mg/L for livestock watering.

Table 2.3 (C) provides the TDS results for the Assiniboine River, along with the results for the specific ion, sulphate. Mean TDS values for the Assiniboine River ranged from 532 to 759 mg/L, indicating that the river is moderately saline. Based on the maximum values, the surface water quality objective for irrigation was exceeded at several locations, due either to the effects of municipal wastewater discharges (at No.8 Highway) or low flow conditions during the winter months (near the Kamsack water treatment plant). Based on the concentration of sulphate (also from Table 2.3 (C)), the water would be considered suitable for livestock watering.

Sodium and chloride (Table 2.3 (D)) are the most significant cations in terms of irrigation use. In the Assiniboine River these constituents exhibited a similar pattern to that of TDS, with the highest values observed downstream during municipal effluent discharges. The water at the upstream sites would be considered suitable for irrigation.

2.3.2 Whitesand River

The Whitesand River is a major tributary of the Assiniboine River in Saskatchewan. It originates at Whitesand Lake, just south of Margo, and flows primarily in an easterly direction before entering the Assiniboine River near Kamsack. The Whitesand River is an intermittent stream that may have no flow for part of the year, but experiences rapid variations in flow because of its direct response to rainfall or snowmelt events.

Water quality monitoring on the Whitesand River has also been sporadic over the years. Monitoring in the upper reaches of the river was largely discontinued in the late 1970s. Table 2.4 (A to D) shows minimum, maximum and mean values for the most significant water quality parameters as measured at nine sites along the river during the period 1980 to 1998. Again, there is a significant variation in the sampling frequency between stations.

2.3.2.1 Microbiological Water Quality

Table 2.4 (A) shows the fecal coliform bacteria counts for the Whitesand River for the period 1980 to 1998, compared to the provincial surface water quality objectives for irrigation and non-contact recreation. As was the case with the Assiniboine, there would not likely be any contact recreation (swimming, water skiing) taking place along the Whitesand River.

Table 2.4
Water Quality Results for the Whitesand River Versus Saskatchewan Surface Water Quality Objectives* for Irrigation, Livestock Watering, and Non-contact Recreation 1980 to 1998

A.

Fecal Coliform Counts				
Station	No. of Samples	Min	Max	Avg
North of Springside	5	10	1180	478
No. 9 Hwy	4	10	40	19
No. 5 Hwy - E. of Canora	4	8	30	15
Opp. Canora WTP	8	8	90	27
Below PFRA Dam	3	23	40	29
1 mile E. of Canora WTP	16	30	230	61
6 miles E. of Canora	19	30	200	49
North of Mikado	2	10	10	10
No. 5 Hwy nr. Kamsack	2	24	66	45

***** *Irrigation=100/100 mL; Non-Contact Recreation=1000/100 mL***

B.

Nutrients:	Total Kjeldahl Nitrogen*				Phosphorous*			
Station	No. of Samples	Min	Max	Mean	No. of Samples	Min	Max	Mean
North of Springside	5	0.8	1.8	1.3	5	0.10	0.27	0.17
No. 9 Hwy.	4	1.8	14.0	5.3	4	0.31	3.30	1.42
No. 5 Hwy - E. of Canora	4	4.2	14.0	7.0	4	0.70	3.10	1.43
Opp. Canora WTP	8	1.6	16.0	4.2	8	0.37	3.10	1.14
Below PFRA Dam	3	1.8	6.5	3.8	3	0.46	1.45	0.87
1 mile E. of Canora WTP	17	1.3	16.5	7.4	17	0.05	2.88	1.12
6 miles E. of Canora	18	0.6	17.8	4.5	19	0.13	2.10	0.67
North of Mikado	2	1.5	1.6	1.55	2	0.21	5.20	2.71
No. 5 Hwy nr. Kamsack	2	1.4	2.1	1.8	2	0.15	0.23	0.19

***** *no set objectives***

C.

	Sulphate				Total Dissolved Solids			
Station	No. of Samples	Min	Max	Mean	No. of Samples	Min	Max	Mean
North of Springside	--	--	--	--	--	--	--	--
No. 9 Hwy.	1	385.0	385.0	385.0	1	1515	1515	1515
No. 5 Hwy - E. of Canora	1	500.0	500.0	500.0	1	1953	1953	1953
Opp. Canora WTP	12	100.0	594.0	348.2	11	373	2659	1402
Below PFRA Dam	--	--	--	--	--	--	--	--
1 mile E. of Canora WTP	17	143.0	700.0	364.5	16	566	2239	1274
6 miles E. of Canora	19	139.0	630.0	318.8	19	550	2824	1134
North of Mikado	--	--	--	--	--	--	--	--
No. 5 Hwy nr. Kamsack	--	--	--	--	--	--	--	--

* Livestock=1000 mg/L
Note: "- - " means no data available

***** *Irrigation=700 mg/L; Livestock=1000 mg/L***

D.

	Chloride				Sodium, dissolved			
Station	No. of Samples	Min	Max	Avg	No. of Samples	Min	Max	Avg
North of Springside	5	10.0	22.0	18.0	--	--	--	--
No. 9 Hwy.	4	22.0	176.0	89.0	1	157.0	157.0	157.0
No. 5 Hwy - E. of Canora	4	14.0	310.0	137.5	1	203.0	203.0	203.0
Opp. Canora WTP	13	18.0	505.0	134.4	12	22.0	405.0	141.66
Below PFRA Dam	3	40.0	256.0	145.3	--	--	--	--
1 mile E. of Canora WTP	16	11.0	502.0	148.0	17	23.0	384.0	137.5
6 miles E. of Canora	17	14.0	356.0	97.7	19	36.0	465.0	114.0
North of Mikado	2	30.0	84.0	57.0	--	-	--	--
No. 5 Hwy nr. Kamsack	2	24.0	66.0	45.0	--	--	--	--

***** *Irrigation=100 mg/L***

***** *Irrigation=100 mg/L***

Overall, the bacteriological quality of the Whitesand at most of the monitoring stations was fairly good. Mean fecal coliform counts from No. 9 Highway all the way downstream to No. 5 Highway near Kamsack ranged from only 10 to 61 organisms per 100 millilitres of water (organisms/100mL), easily meeting the surface water quality objectives. The exception to this was the most upstream site (North of Springside) where mean counts were 478 organisms/100mL with a one-time maximum of 1180 organisms/100mL. However, it should be noted that this value is quite old and the reason for this high value is not known at this time. Additional sampling would help to determine the current microbiological water quality at this station. Two other high counts of 230 and 200 organisms/100mL were recorded downstream of Canora during wastewater discharges from that community. There are no known irrigation or recreational uses of the river in those locations.

2.3.2.2 Nutrients

Table 2.4 (B) shows the concentration of total nitrogen and total phosphorus in the Whitesand River. Mean nitrogen concentrations ranged from 1.3 to 7.4 mg/L, while mean phosphorus ranged from 0.17 to 2.71 mg/L. This confirms that nutrient levels in the Whitesand have been highly variable over the years. Again, the river flows through an area of nutrient-rich farmland and it is expected that runoff from the adjacent land would affect nutrient levels in the river. In addition, there are localized impacts from municipal wastewater discharges at several locations along this river reach. The variation in nutrient concentration can also be attributed to the large fluctuations in water flows.

2.3.2.3 Water Chemistry

Total dissolved solids (TDS) and sulphate concentrations for the Whitesand River are shown in Table 2.4 (C). Mean TDS levels ranged from 1134 to 1953 mg/L, indicating that the water is quite saline. Based on the mean concentrations of sulphate (at those stations where data were available) the water would be considered suitable for livestock watering.

Sodium and chloride concentrations (Table 2.4 (D)) exceeded the provincial surface water quality objective for irrigation at a number of stations, indicating that there would be some limitations to using the water for irrigation depending on the soil and crop type.

2.3.3 Good Spirit Lake

Good Spirit Lake is a relatively shallow recreational lake in east-central Saskatchewan located about 15 kilometres southwest of Canora. During the summer months, the lake occasionally experiences nuisance growths of algae. The water quality monitoring of Good Spirit Lake has also been sporadic over the years. Data for the period 1993 to 1998 shown in Table 2.5 (A to D) indicates that the water quality has been quite good overall, and is typical of shallow lakes in this region.

Table 2.5
Water Quality Results for Good Spirit Lake Versus Saskatchewan Surface Water Quality Objectives* Set for Irrigation, Livestock Watering, And Recreation (Contact and Non-contact), 1993 to 1998

(A)

Fecal Coliform Counts				
Station	**No. of Samples**	**Min**	**Max**	**Avg**
North End	1	10	10	10
Canora Beach	4	2	10	5
Mid Lake	3	10	14	11
Burgis Beach	4	2	10	4
South End	1	10	10	10
Provincial Park Beach	5	2	10	5

** Irrigation=100/100 mL; Contact Recreation=200/100 mL; Non-Contact Recreation=1000/100 mL*

(B)

Nutrients:	Total Kjeldahl Nitrogen*				Phosphorous*			
Station	**No. of Samples**	**Min**	**Max**	**Avg**	**No. of Samples**	**Min**	**Max**	**Avg**
North End	1	1.9	1.9	1.9	1	0.09	0.09	0.09
Canora Beach	1	1.3	1.3	1.3	6	0.07	0.15	0.11
Mid Lake	3	1.7	2.5	2.1	3	0.05	0.08	0.07
Burgis Beach	1	1.8	1.8	1.8	6	0.08	0.16	0.11
South End	1	1.4	1.4	1.4	1	0.23	0.23	0.23
Provincial Park Beach	2	1.5	1.6	1.55	7	0.07	0.16	0.11

** no set objectives*

(C)

	Sulphate				Total Dissolved Solids (calculated)			
Station	**No. of Samples**	**Min**	**Max**	**Avg**	**No. of Samples**	**Min**	**Max**	**Avg**
North End	1	397.0	397.0	397.0	1	907	907	907
Canora Beach	1	303.0	303.0	303.0	1	752	752	752
Mid Lake	3	290.0	386.0	325.7	3	748	894	798
Burgis Beach	1	309.0	309.0	309.0	1	759	759	759
South End	1	386.0	386.0	386.0	1	899	899	899
Provincial Park Beach	2	304.0	386.0	345.0	2	748	891	820

** Livestock=1000 mg/L*

** Irrigation=700 mg/L; Livestock=1000 mg/L*

(D)

	Chloride				Sodium, dissolved			
Station	**No. of Samples**	**Min**	**Max**	**Avg**	**No. of Samples**	**Min**	**Max**	**Avg**
North End	1	9.0	9.0	9.0	1	26.0	26.0	26.0
Canora Beach	1	7.0	7.0	7.0	1	20.0	20.0	20.0
Mid Lake	3	6.0	9.0	7.0	3	20.0	25.0	21.7
Burgis Beach	1	5.0	5.0	5.0	1	20.0	20.0	20.0
South End	1	9.0	9.0	9.0	1	25.0	25.0	25.0
Provincial Park Beach	2	6.0	8.0	7.0	2	19.0	26.0	22.5

** Irrigation=100 mg/L*

** Irrigation=100 mg/L*

2.3.3.1 Bacteriological Water Quality

As shown in Table 2.5 (A), fecal coliform bacteria counts were very low over the period of record, easily meeting the surface water quality objectives for all expected uses, including contact and non-contact recreation.

2.3.3.2 Nutrients

Table 2.5 (B) provides the concentration of major plant nutrients (nitrogen and phosphorus). Although the levels of these parameters were not excessive in Good Spirit Lake, they were in adequate supply to sustain abundant growth of algae and other aquatic plants under the right conditions. Naturally available nutrients in the lake, together with warm, sunny weather during spring and summer are the primary causes of nuisance algal growths in many prairie lakes. This is a natural situation and does not indicate a water pollution concern.

2.3.3.3 Water Chemistry

Table 2.5 (C) shows that the water in Good Spirit Lake was quite mineralized. Mean TDS levels ranged from 752 to 907 mg/L, slightly exceeding the surface water quality objective for irrigation. Nevertheless, the water would likely be suitable for irrigation of most crops depending on the species and soil type in the area. Based on the mean sulphate levels of 303 to 397 mg/L, the water would be suitable for livestock watering.

With respect to irrigation use, sodium and chloride were found in concentrations well below the provincial surface water quality objectives for these parameters (see Table 2.5 (D)).

2.3.4 Fishing Lake

Fishing Lake is a medium-sized recreational lake situated in east-central Saskatchewan about 30 kilometres southeast of Wadena. The water quality of Fishing Lake has typically been rated quite high due to its clarity and lack of algal growth.

A recreational lake assessment was carried out on Fishing Lake by SERM in 1994/95, and occasional monitoring has been done since that time. Table 2.6 (A to D) provides the minimum, maximum and mean data for the monitoring done on Fishing Lake to date.

2.3.4.1 Microbiological Water Quality

As shown in Table 2.6 (A), the bacteriological quality of Fishing Lake was excellent during the sampling period. Mean fecal coliform counts were only 5 organisms per 100mL of water at all stations, with maximum counts of only 10 organisms/100mL. These results indicate good quality for contact and non-contact recreation.

Table 2.6
Water Quality Results for Fishing Lake Versus Saskatchewan Surface Water Quality Objectives* for Irrigation, Livestock Watering, And Recreation (Contact and Non-contact), 1993 to 1998

(A)

Fecal Coliform Counts				
Station	**No. of Samples**	**Min**	**Max**	**Avg**
Buckhorn Bay	15	2	10	4
Saskin Beach	16	2	10	5
Southwest Bay	15	2	10	4
Leslie Beach	16	2	10	5
Southeast Bay	15	2	10	4

** Irrigation=100/100 mL; Contact Recreation=200/100 mL; Non-Contact Recreation=1000/100 mL*

(B)

Nutrients:	Total Kjeldahl Nitrogen*				Phosphorous*			
Station	**No. of Samples**	**Min**	**Max**	**Avg**	**No. of Samples**	**Min**	**Max**	**Avg**
Buckhorn Bay	10	0.7	1.7	1.2	10	0.02	0.06	0.04
Saskin Beach	10	0.5	1.6	1.2	10	0.02	0.07	0.04
Southwest Bay	10	0.5	1.6	1.2	10	0.02	0.04	0.03
Leslie Beach	10	0.7	2.0	1.4	10	0.02	0.05	0.03
Southeast Bay	11	0.5	1.8	1.3	11	0.02	0.22	0.06

** no set objectives*

(C)

	Sulphate				Total Dissolved Solids (calculated)			
Station	**No. of Samples**	**Min**	**Max**	**Avg**	**No. of Samples**	**Min**	**Max**	**Avg**
Buckhorn Bay	10	1914	2794	2378	10	3088	4368	3746
Saskin Beach	10	1905	2832	2376	10	3074	4417	3746
Southwest Bay	10	1897	2776	2389	10	3065	4339	3759
Leslie Beach	10	1931	2792	2395	10	3106	4366	3772
Southeast Bay	11	512	2743	2200	11	1369	4308	3523
** Livestock=1000 mg/L*					** Irrigation=700 mg/L; Livestock=1000 mg/L*			

(D)

	Chloride				Sodium, dissolved			
Station	**No. of Samples**	**Min**	**Max**	**Avg**	**No. of Samples**	**Min**	**Max**	**Avg**
Buckhorn Bay	10	50.0	78.0	68.4	10	277.0	410.0	343.8
Saskin Beach	10	50.0	74.0	65.6	10	276.0	414.0	344.2
Southwest Bay	10	52.0	76.0	66.1	10	278.0	412.0	343.3
Leslie Beach	10	53.0	78.0	65.8	10	280.0	418.0	345.1
Southeast Bay	11	8.0	75.0	60.3	11	86.0	414.0	320.5
** Irrigation=100 mg/L*					** Irrigation=100 mg/L*			

2.3.4.2 Nutrients

Table 2.6 (B) shows that nutrient concentrations were quite low during the sampling period, with mean total nitrogen ranging from 1.2 to 1.4 mg/L, while mean total phosphorus fell in the range of 0.03 to 0.06 mg/L. These values would be considered as 'natural' levels for a lake in this region. Nuisance growths of algae and aquatic plants that limit recreational or other uses would not generally be expected to occur.

2.3.4.3 Water Chemistry

Table 2.6 (C) shows that mean total dissolved solids (TDS) ranged from 3523 to 3772 mg/L, exceeding the surface water quality objectives of 700 mg/L for irrigation use and 1000 mg/L for livestock use. With such high TDS levels, and with mean sodium concentrations ranging from 320.5 to 345.1 mg/L (Table 2.6 (D)), the water in Fishing Lake would be considered unsuitable for irrigation of most crops, except for those that are very tolerant to sodium and other salts.

Based on the levels of sulphate shown in the Table 2.6 (C), the water in Fishing Lake would be considered unsuitable for livestock watering

2.4 Water Quality in Manitoba

Most of the available water quality data for the Manitoba portion of the Upper Assiniboine River Basin focuses on the main water bodies of the region. The location of sampling stations where Manitoba Conservation monitors water quality is shown on Table 2.7. Lake of the Prairies was formed by a dam located at the confluence of the Shell River and the Assiniboine River and extends northwesterly across the Manitoba border into Saskatchewan. The Shell River originates in the Duck Mountains on the northeastern edge of the Basin boundary and has a gross drainage area of 1999 km^2. Boggy Creek empties into the Lake of the Prairies at the Manitoba border and has a gross drainage area of 435 km^2. Other streams in the area would include Cupar, Blackbird, Conjuring, Smith, and Thunder creeks. However, water quality data for these smaller streams is limited and they have not been included in any water quality synopsis.

Table 2.7
Location of Water Quality Sampling Stations

Name	Latitude	Longitude
Big Boggy Creek at PR. No.484	51 16.65	101 29.03
Shell River at PR.No. 594, South of Boggy Creek	51 27 00	101 20 00
Shell River at PR. No. 583, South of Roblin	51 10 00	101 20 00
Shell River at PTH No. 83	50 57 00	101 21 00
Shell River at PR No. 367, North East of San Clara	51 31 00	101 23 00
Shell River at PR No. 483, North West of Merridale	51 21 00	101 15 00
Shell River at PR No. 591, North East of Roblin	51 15 00	101 15 00
Shell River at PTH No 5, East of Roblin	51 13 00	101 13 00
Shell River at PR No. 589, South East of Roblin	51 00 00	101 18 00
Shell River at PR No. 583 at Shevlin	51 12 00	101 13 00
Lake of the Prairies above Dam	50 58 00	101 25 00
Lake of the Prairies Shell River Mouth	50 58 00	101 23 00
Lake of the Prairies, South of PTH No. 5	51 13 00	101 31 00

In Manitoba, surface water quality objectives have been derived for the protection of beneficial water uses (Williamson, 1988). The major water uses of Lake of the Prairies and its tributaries are recreation, habitat for aquatic life and wildlife, and livestock watering. The following section provides a brief overview of the water quality for the three main streams.

2.4.1 Lake of the Prairies

The Lake of the Prairies (Shellmouth Reservoir) has a mean depth of 7 metres and a surface area of 52 km^2. The Lake of the Prairies was created to provide downstream flood control protection and to provide a consistent water supply to downstream users as far away as Portage la Prairie. The lake is a heavily utilized recreational area and supports an excellent walleye sport fishery worth close to $2,000,000 to the local economy.

2.4.1.1 Fecal Coliform

Table 2.8-A shows the mean fecal coliform data for five stations along Lake of the Prairies, ranging from the dam (LP-1) to the most upstream station (LP-5) at the Manitoba border for the period 1991 to 1993. Fecal coliform bacteria originate in the digestive tracts of warm-blooded animals. They are used as indicator organisms and their presence usually suggests contamination by human or animal faeces. When found in large numbers they are often associated with disease causing organisms. As in Saskatchewan, Manitoba's fecal coliform objective is set at 200 organisms per 100 mL for the protection of primary recreation activities, such as swimming or water skiing. Fecal coliform concentrations ranged from 10 to 70 organisms per 100 mL and were well below this objective, indicating that primary recreation is adequately protected in Lake of the Prairies.

2.4.1.2 Phosphorous

Manitoba's surface water objective for total phosphorous was established at 0.025 mg/L in order to limit the growth and development of nuisance algal blooms in lakes and reservoirs. Table 2.6-B indicates that mean phosphorous concentrations increase toward the shallower portion of the lake at the Manitoba-Saskatchewan border. It is also clear that the objective is exceeded throughout the lake. Consequently, the potential for widespread algal blooms is high, particularly during the open water season. Reduction in loading from external phosphorous sources is needed before a reduction in algal blooms is likely to occur. However, internal loading of phosphorous within the lake is a major contributor to the annual phosphorous loading (Fortin and Gurney, 1998). This recycling source of phosphorous will buffer the benefits of reduced external loading and create a lag time before any observed decrease in the extent of algal blooms can be observed.

Table 2.8
Water Quality Data for Five Stations Along the Lake of the Prairies, Ranging From the Dam (LP-1) to the Most Upstream Station (LP-5) At the Manitoba Border for the Period 1991 to 1993

	Station	No. of Samples	Mean	Median	Minimum	Maximum	Water Quality Objective
	Fecal Coliform Organisms per 100 mg/L						
A.	LP 1	38	10.0	10.0	0.0	10.0	200
	LP 2	37	10.0	10.0	0.0	10.0	200
	LP 3	38	10.0	10.0	0.0	10.0	200
	LP 4	37	10.0	10.0	0.0	10.0	200
	LP 5	37	11.0	10.0	1.0	70.0	200
	Phosphorous mg/L						
B.	LP 1	43	0.100	0.089	0.025	0.292	0.025
	LP 2	42	0.099	0.082	0.027	0.291	0.025
	LP 3	42	0.118	0.101	0.033	0.286	0.025
	LP 4	44	0.161	0.108	0.042	0.446	0.025
	LP 5	44	0.205	0.152	0.055	0.705	0.025
	Dissolved Oxygen mg/L						
C.	LP 1	41	9.40	9.00	6.10	13.60	47% saturation
	LP 2	42	10.00	9.40	5.20	18.50	47% saturation
	LP 3	40	10.00	10.15	5.10	14.60	47% saturation
	LP 4	41	10.10	10.00	6.40	18.10	47% saturation
	LP 5	44	10.00	9.80	0.50	21.00	47% saturation

2.4.1.3 Dissolved Oxygen

Manitoba's dissolved oxygen objective of 47 percent saturation has been set for the protection of aquatic life commonly found in cool water habitat. In order to achieve this objective, the dissolved oxygen concentrations need to be greater than or equal to 5 mg/L throughout most of the year. Fish kills will likely occur at dissolved oxygen concentrations of less than 1 mg/L, while some fish species may be under stress at concentrations of less than 3 mg/L. Data for the period 1991 to 1993 indicate an average concentration of close to 10 mg/L across the lake (Table 2.8-C). Wind action on the lake maintains a well mixed water column, recirculating oxygen throughout the lake. Oxygen profiles in the lake have shown oxygen levels below the objective at the bottom depths of the lake, but never for prolonged periods. Overall, the dissolved oxygen levels observed in the lake support the protection of aquatic life.

2.4.1.4 Total Dissolved Solids/Sulphate

Sulphate concentrations ranged from 20 to 254 mg/L along the length of the lake only slightly exceeding the irrigation objective of 250 mg/L two percent of the time. Overall, the water is suitable for irrigation, however irrigation is not prevalent along the lake and is not an important use. Maximum TDS values ranged from 530 to 650 mg/L and maximum sulphate concentrations of 254 mg/L were well below the guidelines for livestock watering of 3000 mg/L and 600 mg/L, respectively.

2.4.2 Shell River

Lake of the Prairies is a mainstream lake with most of the inflow into the lake coming from the Assiniboine River and its upstream tributaries in Saskatchewan. The Shell River is the main Manitoba source of inflow into the lake and comprises approximately 11 percent of the gross drainage area to the lake. Most of the historic water quality data for the Shell River comes from WQ 172, the most downstream station before the river flows into the lake, with information dating back three decades from the early 1970s to the 1990s. Mean concentrations over each decade, of approximately equal sample sizes, have been calculated for comparison.

2.4.2.1 Fecal Coliform

The mean fecal concentrations for the Shell River, as shown in Table 2.9-A, are all well below the Manitoba water quality objective of 200 organisms per 100 mL. It appears that the water quality has shown some improvement over time, with mean concentrations decreasing from the beginning period of data collection. Over the period of the 1970s to1980s, individual samples have exceeded the objective eight percent of the time, ranging in values from 0 to 750 organisms per 100 mL. No exceedances were observed during the 1990s. Overall, the objective is currently being met in the Shell River.

2.4.2.2 Phosphorous

The Manitoba objective for phosphorous in streams has been set at 0.05 mg/L in order to prevent excess macrophyte or algal blooms. This objective has been exceeded 57 percent to 70 percent of the time for the period of record. Table 2.9-B shows that the mean concentration of total phosphorous has remained relatively consistent in the 0.06 to 0.07 mg/L range, possibly indicating that natural and anthropogenic sources of phosphorous input to the Shell River have been comparatively stable.

2.4.2.3 Dissolved Oxygen

Historically, dissolved oxygen concentrations are high with mean concentrations ranging between 10 to 11 mg/L, well within the dissolved oxygen objective (Table 2.9-C). Minimum concentrations as low as 3.0 mg/L were occasionally observed during the low flow and ice covered months of January and February. Concentrations less than 5 mg/L were only observed four percent of the time during the period of record. The dissolved oxygen levels observed in the Shell River are presently sufficient to support the protection of aquatic life.

Table 2.9
Historic Water Quality Data for the Shell River
From the Most Downstream Station Before the River Flows into the Lake
Dating from Three Decades Between the Early 1970s to the 1990s

	Station	No. of Samples	Mean	Median	Minimum	Maximum	Water Quality Objective
	Fecal Coliform Organisms per 100 mg/L						
A.	1970s	41	79.0	9.0	0.0	750.0	200
	1980s	46	45.0	4.0	0.0	460.0	200
	1990s	37	19.0	10.0	1.0	80.0	200
	Phosphorous mg/L						
B.	1970s	50	0.062	0.030	0.010	0.600	0.025
	1980s	42	0.067	0.030	0.012	0.600	0.025
	1990s	47	0.060	0.044	0.014	0.253	0.025
	Dissolved Oxygen mg/L						
C.	1970s	48	10.20	10.20	6.80	14.20	47% saturation
	1980s	47	9.70	9.50	3.00	13.40	47% saturation
	1990s	47	10.10	9.80	6.30	13.50	47% saturation

2.4.2.4 Total Dissolved Solids/Sulphate

The maximum sulphate concentrations were derived from the1970s and 1990s data only and range between 327 and 385 mg/L. These values are well below the livestock watering objective of 600 mg/L but do exceed the irrigation objective of 250 mg/L, 27 percent and 50 percent of the time respectively during the two sampling periods. The exceedences of sulphate do not support irrigation as a water use however, like the Lake of the Prairies, irrigation is not an important use of the Shell River. Maximum TDS concentrations are well below the livestock watering objective of 3000 mg/L, ranging in values between 850 and 900 mg/L

2.4.3 Boggy Creek

Boggy Creek is a shallow stream that derives most of its flow during the spring snowmelt and after significant rainfall events. Water quality data for Boggy Creek are available from a water quality station located just upstream of the creek's outlet to Lake of the Prairies. Information is available from 1991 to 1993.

2.4.3.1 Fecal Coliform

The mean fecal coliform concentration of 32 organisms per 100 mg/L is well below the recreation objective of 200 organisms per 100 mg/L. Fecal coliform concentrations as high as 410 per 100 mg/L were observed during the summer, but never for extended periods. Livestock were pastured upstream of the site and there was abundant beaver activity in the area, which may have contributed to the higher values.

2.4.3.2 Phosphorous

The mean total phosphorous concentration of 0.126 mg/L is well above the Manitoba guideline for streams of 0.05 mg/L. Bank erosion and weathering have an important role in the concentration of total phosphorous found in Boggy Creek. The highest values of total phosphorous (0.705 mg/L) were associated with the high spring runoff when particulate phosphorous made up over 70 percent of the total concentration.

2.4.3.3 Dissolved Oxygen

Mean dissolved oxygen concentrations of 10.3 mg/L were well above the oxygen objective for the protection of aquatic life. Minimum values observed were also well above the guideline, so that oxygen levels are quite sufficient to sustain aquatic life in Boggy Creek.

2.4.3.4 Total Dissolved Solids

Mean TDS concentrations of 956 mg/L and mean sulphate concentrations of 367 mg/L are both well below the livestock watering objective. However, the sulphate objective for irrigation of 250 mg/L is exceeded by the concentrations found in Boggy Creek, rendering it unsuitable for irrigation.

In conclusion, all the beneficial uses are supported on the Manitoba side of the Upper Assiniboine River Basin. Total phosphorous concentrations exceed the objective in both the streams and lake. The greatest impact of this exceedence is on Lake of the Prairies where the rapid development of algal blooms can diminish the aesthetic appeal of the lake. Exceedences of the sulphate guideline in both Boggy Creek and Shell River make it unsuitable for irrigation although this is not one of the primary uses of either stream.

2.5 Trends in Water Quality at the Kamsack Prairie Provinces Water Board (PPWB) Station

To determine long-term trends in water quality, the Assiniboine River at Kamsack data for the period 1981 to 1997 were reviewed by Environment Canada. Time series graphs were produced and non-parametric trend tests were conducted to identify trends in water quality parameters in the Assiniboine River at the Kamsack site. The results were encouraging, as no parameters showed a long-term increasing trend in concentration and a few (total nickel, total coliform, and alpha BHC) displayed long-term decreasing trends in concentration.

The water quality results at Kamsack were compared to the PPWB Water Quality Objectives to identify possible variables of concern in the river. The dissolved oxygen objective was exceeded periodically, mainly under winter ice conditions, which is often typical of intermittent prairie streams. The dissolved manganese objective was also exceeded but mainly during the winter months. The total phosphorus objective, established in 1990, was occasionally exceeded but this objective is out dated and under review. The report entitled, *Water Quality Trends in the Assiniboine River at the Interprovincial Boundary* reviews water quality conditions in the Assiniboine River in more detail and is included as Appendix III of this report.

2.6 Summary

In summary, a review of the available data for several water bodies in the Upper Assiniboine River Basin indicates that in general the water quality is suitable for its expected uses. There are several areas where limitations to uses such as irrigation are evident. It is important to note that in some cases the assessment is based on a limited quantity of data. Additional monitoring would be required to update the water quality conditions at those locations. The PPWB sampling site on the Assiniboine River near Kamsack provides an ongoing measure of water quality trends in the upper reaches of the Basin and provides the only up-to-date data. However, Saskatchewan has expressed a concern that the sampling station is too close to the point of wastewater discharge from Kamsack.

2.7 Recommendations

1) Monitoring for dissolved oxygen, total phosphorous and dissolved manganese should continue at a frequency that is capable of detecting long-term trends in water quality. This is recommended since levels of these variables already exceed the PPWB Water Quality Objective for the Assiniboine River and could potentially have a detrimental effect on downstream users in the Basin.

2) Methods of operational effluent release procedures in coordination with Assiniboine River stream flows should be reviewed. A reduction of nutrients in the Assiniboine River may have the potential to reduce accelerated aquatic weed growth in the river.

3) A monitoring program should be carried out to collect additional data in order to confirm the current status of water quality conditions in the Basin. Water quality monitoring carried out on the major waterbodies in the Saskatchewan portion of the Upper Assiniboine River Basin has provided some baseline data for the period 1980 to 1998. However, the sampling frequency has been highly variable and some of the results are quite dated.

2.7.1 Brochures

Appendix V of this report is an 18-page booklet entitled, "Water Quality in the Upper Assiniboine River Basin" that was published in January 2000. This document was jointly produced as an initiative of the Governments of Saskatchewan, Manitoba, and Canada. Two sections within this booklet provide a brief overview of water quality and trends within the Basin. They are "Water Quality in the Basin, pages 3 to 6", and "Trends in Water Quality, pages 6 to 9".

3 Drainage and Water Quality

3.1 Introduction

Drainage was an important part of settlement of the Prairies and, until recently, governments have supported drainage activities directly and indirectly. Increased mechanization in farming practices, along with a trend to larger land holdings has led to increased drainage activity. Because commodity prices have not increased at the same rate as input costs, farmers have increased their land base in an effort to make a living by conventional farming methods. Larger land holdings mean that more work must be completed in the same amount of time, so larger implements are often used to complete fieldwork quicker. Larger implements make navigation around wetlands more difficult and time consuming. The resulting economic inefficiency and inconvenience are often cited as reasons for removal of wetlands from cultivated lands. Some producers may view any form of wildlife habitat as competition detrimental to their farming operation.

3.2 Legislation Governing Water Quality as it Pertains to Drainage

The Water Corporation Act in Saskatchewan and *The Water Rights Act* in Manitoba legislate drainage in their respective provinces. Neither act governs the effects of drainage on water quality.

3.2.1 Federal

In the past, the *Western Grain Transportation Act* (WGTA) and the Canadian Wheat Board's (CWB's) acreage based quota allocation influenced drainage activities. The WGTA lowered the farmers' cost of transporting grains and oilseeds to export position making their production more profitable. With relatively higher profits from growing grains and oilseeds compared to other land uses, farmers had an incentive to increase their acreage seeded to grains and oilseeds. The CWB's acreage based quota allocation was set up to give every farmer fair access to market grain. By using acreages to calculate a farmer's allocation, farmers could increase their allocation by increasing their cultivated acreage. The incentive to increase their allocation may have encouraged farmers to drain wetlands, break native grassland, and clear trees.

3.2.2 Saskatchewan

The Government of Saskatchewan's wetland policy supports the sustainable management of wetlands to maintain the multiple benefits they provide, now and into the future. Provincial government departments and agencies that participated in policy development and deliver land/water use programs and policies have been directed to guide policy implementation. These include Saskatchewan Wetland Conservation Corporation (lead in policy implementation), Saskatchewan Environment and Resource Management, Sask Water, Saskatchewan Agriculture and Food, and Saskatchewan Municipal Affairs, Culture and Housing. One of the objectives is to encourage sustainable management of wetlands on public and private lands to maintain their functions and benefits. Another is to restore or rehabilitate degraded wetland ecosystems where previous destruction or alteration has resulted in a significant loss of wetland functions or benefits. One of the principles underlying these objectives is that the rights of landowners and their role in the stewardship of land are recognized and their ongoing involvement is assured. However, there is no program that involves the landowner, agricultural land drainage and wetlands in a way that effects maintaining or improving water quality. This might take place through integrated planning of land use and drainage activities with local landowner cooperation. The *Water Corporation Act* may be able to accommodate this approach through administration of a modified drainage approval process that recognizes water quality with local landowner cooperation. In order to achieve this there would need to be a high level of compliance with the legislation.

The Conservation Easements Act (1996) introduced conservation easements and programs providing tax incentives for wetland retention. These programs offer options to landowners faced with land use decisions. The concept of conservation easements or development easements is the manner in which landowners can receive the monetary benefit from changing the land use. This may, indirectly, contribute to improving water quality.

Improving the administration of *The Water Corporation Act* in harmony with the wetland policy and encouraging sustainable management of wetlands on public and private lands to maintain their functions and benefits can lead to water quality improvements that will benefit both the landowner and the environment.

3.2.3 Manitoba

Manitoba has wetland conservation policies similar to Saskatchewan that suggest, "wetlands shall, where possible, be conserved." Manitoba's Water Policy 2.2 suggests that, "wetland retention shall be promoted primarily by the provision of incentives, but with regulation where required, not only as essential elements of water conservation and protection, but also as key measures to reduce siltation impacts, downstream flooding, and non-point source pollution." This policy suggests that the Government of Manitoba will "regulate activities and enforce compliance, where necessary, to ensure that the public's general conservation interests are not undermined" and "review and modify government legislation and policy to ensure that they support conservation". *The Water Rights Act*, which has been used to regulate drainage in Manitoba, does not presently support this policy.

3.2.4 Drainage

Saskatchewan and Manitoba landowners are required, by law, to apply for and receive a license to construct drainage works prior to construction. There are many unlicensed works in both provinces, the impact of which has not been quantified. Impacts to water quality are not presently a consideration in the provinces' drainage licensing processes.

Removal of wetland surface storage areas through drainage may allow nutrients, contaminants, and sediments to flow into rivers and streams, which has an effect on water quality in these receiving waterways.

Wetlands significantly reduce levels of phosphorous, nitrogen, biochemical oxygen demand (BOD), and coliforms while providing valuable habitat for a variety of wildlife. Wetlands are said to be one of the most productive ecosystems. Wetlands may be closely linked with groundwater in that they may be recharge or discharge sites for groundwater.

Drainage ditches can carry water contaminated by high concentrations of salts and other chemicals from the catchment area. Evaporation of these waters can further concentrate the mineral content. Straight, non-vegetated drainage channels increase the speed of runoff events. This increases the likelihood of erosion and subsequent sedimentation. Increased turbidity of the runoff water is likely to impact fish and other aquatic life. Given an increase in water flow speeds, drainage may also contribute to the duration and/or severity of the flood peak in small to moderate flood events.

Larger flood events lead to damage from erosion and nutrient/contaminant loading, increasing the area of affected flood plains. Larger floods may increase sediment loading to reservoirs, lakes, and streams, but may improve instream water quality due to dilution.

3.3 Literature Review

3.3.1 Dillon Consulting Limited: *Upper Assiniboine River Basin Water Quality Study - Final Report, November 1998*

The literature review completed by Dillon Consulting Limited is an examination of drainage of cultivated lands. At present, drainage activities continue despite the lack of government financial assistance because many landowners perceive drainage as a cost beneficial land improvement activity, without considering the societal costs of drainage. Greater effort has been made to reduce impacts of wetland drainage on private and public lands in recent years. There is a heavy reliance on legislation to provide this protection. The following are water quality concerns related to drainage:

- Nutrients entering surface and groundwater supplies from external sources such as agricultural fertilizer can impact water quality, creating negative consequences for wildlife, livestock, human and aquatic biota. Nutrient loading of surface water may result in algal growth. This may cause reductions or changes in aquatic biota due to the shading effect of algae in the water column, the reduction of water flow in the water body or lowering of dissolved oxygen levels that result during decomposition of algae. Species of algae may develop which are highly toxic to humans, livestock and wildlife. Algae may negatively impact drinking water quality by imparting odour and taste (Tones, 1987). Some of the chemical treatment methods for controlling algal growth in drinking water supplies, such as copper sulphate, may also negatively impact water quality.

- High concentrations of ammonia nitrogen may occur in water sources as a result of fertilizer runoff facilitated by drainage. Increased concentrations of ammonia nitrogen in surface water can stimulate the growth of algae and aquatic plants. Ammonia readily converts to nitrate and nitrite through a chemical reaction which uses dissolved oxygen. Reduction of dissolved oxygen can negatively impact aquatic biota. High levels of nitrogen in groundwater may also create a health problem called blue-baby syndrome in infants, which can lead to respiratory failure. High levels of nitrogen in water supplied to livestock can result in weight loss and poor feed conversion (USCATST, 1992; CCME, 1987).

- Phosphorous laden soil particles may be added to a water body by erosional surface runoff facilitated by drainage. Particulate phosphorous is released in solution with water and may result in impacts to water quality. In its dissolved form, phosphorous is readily taken up by plants and algae (Beck, 1996). Phosphorus is often a greater concern for aquatic systems than nitrogen because it is generally considered the limiting factor for the growth of freshwater phytoplankton such as algae (CCME, 1987).

- Pesticides may contaminate surface and ground water. Drainage of lands on which these chemicals are used may facilitate their movement to water bodies. Pesticides can be toxic to humans, livestock and wildlife depending on a number of factors including the type of pesticide and dilution rate.

- Agricultural land drainage may facilitate the accumulation of heavy metals in receiving water bodies.

- Agricultural land drainage may aggravate soil erosion and deposition impacts on the receiving water body by increasing water flow rates along disturbed soils. Increased silt loading and turbidity can present problems for recreation use of water bodies because of decreased visibility (Fisheries and Oceans, 1992). Sediments are also known to cover fish spawning areas. Sedimentation, the settling out of suspended sediments, can also affect the storage capacity and life span of reservoirs (Kuiper, 1962).

- Agricultural land drainage which includes the removal of wetlands may cause impacts to surface and ground water. Wetlands significantly reduce phosphorous, nitrogen, BOD and coliforms. Removal of wetlands reduces this function. Drainage of marshlands may impact the recharge and discharge of the aquifer and result in groundwater quality changes (van der Kamp, 1989).

- Gobert (1983) outlined the potential impact of large scale drainage projects on flood conditions in the Basin. With the addition of drainage waters, the duration and peak flows of small floods (1:2 year flood) increase, creating flooding that will last as much as a week longer than under natural conditions.

A complete copy of the Dillon Consulting Limited report forms Appendix II of this report.

3.4 Summary

Drainage may reduce water quality of the receiving water body. Some of the impacts of agricultural land drainage on water quality include nutrient loading, pesticide contamination, heavy metal contamination, erosion and sedimentation and removal of the natural buffering capabilities of wetlands through their drainage. Ammonia nitrogen, nitrates and nitrites can negatively impact water quality of receiving water bodies when transported by a drainage system. Particulate phosphorous may be transported downstream to receiving water bodies via agricultural drainage when soil particles erode and are carried with the water flow.

Concentration of pesticides in the receiving water body may occur as a result of runoff from cultivated lands due to drainage. Heavy metals may accumulate in the receiving water body if agricultural fields are drained. Erosion and sedimentation resulting from agricultural land drainage may contribute to infilling of reservoirs, nutrient and heavy metal loading and accumulation of pesticides. Furthermore, water quality benefits accrued by wetland retention are lost when those wetlands are drained. Lastly, duration of flooding and peak flow rates are increased during small flood events with addition of drainage waters.

3.5 Recommendations

The Water Quality Committee makes the following recommendations:

1) Water quality should be taken into consideration when evaluating drainage projects. Drainage project approvals should be coordinated so that more efficient monitoring of water quality is possible. Criteria for rating or evaluating drainage projects should be established and used since no such evaluation currently is applicable. The evaluation process would include such items as soil texture, slope, seeding system, extent of residue cover, significant rainfall and runoff events, average annual precipitation and impact on wetlands. A code of practise should be developed for construction of drainage projects to reduce project caused impacts to water quality.

2) Watershed-based planning should be undertaken to account for the cumulative impacts of drainage on water quality. Maintenance of existing wetlands should be regulated and encouraged to ensure some surface water storage within the Basin. This would reduce impacts of drainage on small flood events and would improve water quality by utilizing the wetlands' ability to filter out nutrients and sediments.

3) Maintenance of riparian areas around water courses and water bodies should be encouraged. Preference should be given for licensing of drainage works that include establishment of vegetation cover such as grasses to protect the ditch from erosion. Buffer strips or bush adjacent to water courses or water bodies should be protected to reduce the potential for erosion or contamination of the receiving water body.

4 Livestock and Water Quality

4.1 Introduction

Agriculture is the dominant landscape activity in the Upper Assiniboine River Basin, with livestock being an integral part of this activity. This chapter discusses the current livestock inventory within the Basin; the regulatory control of livestock production; and provides clarification of some sections of the literature review conducted by Dillon Consulting Limited. This chapter also reports on the demonstration/special projects that were conducted in the Basin and involved the Water Quality Committee.

Approximately 56.2 percent of the farms within the boundary of the Basin raise some type of livestock (Statistics Canada, 1998). Figure 3.1 (map) shows the percentage of farms by rural municipality within the Basin that have livestock on site. Figures 3.2 to 3.6 indicate the respective numbers of animals by species per rural municipality.

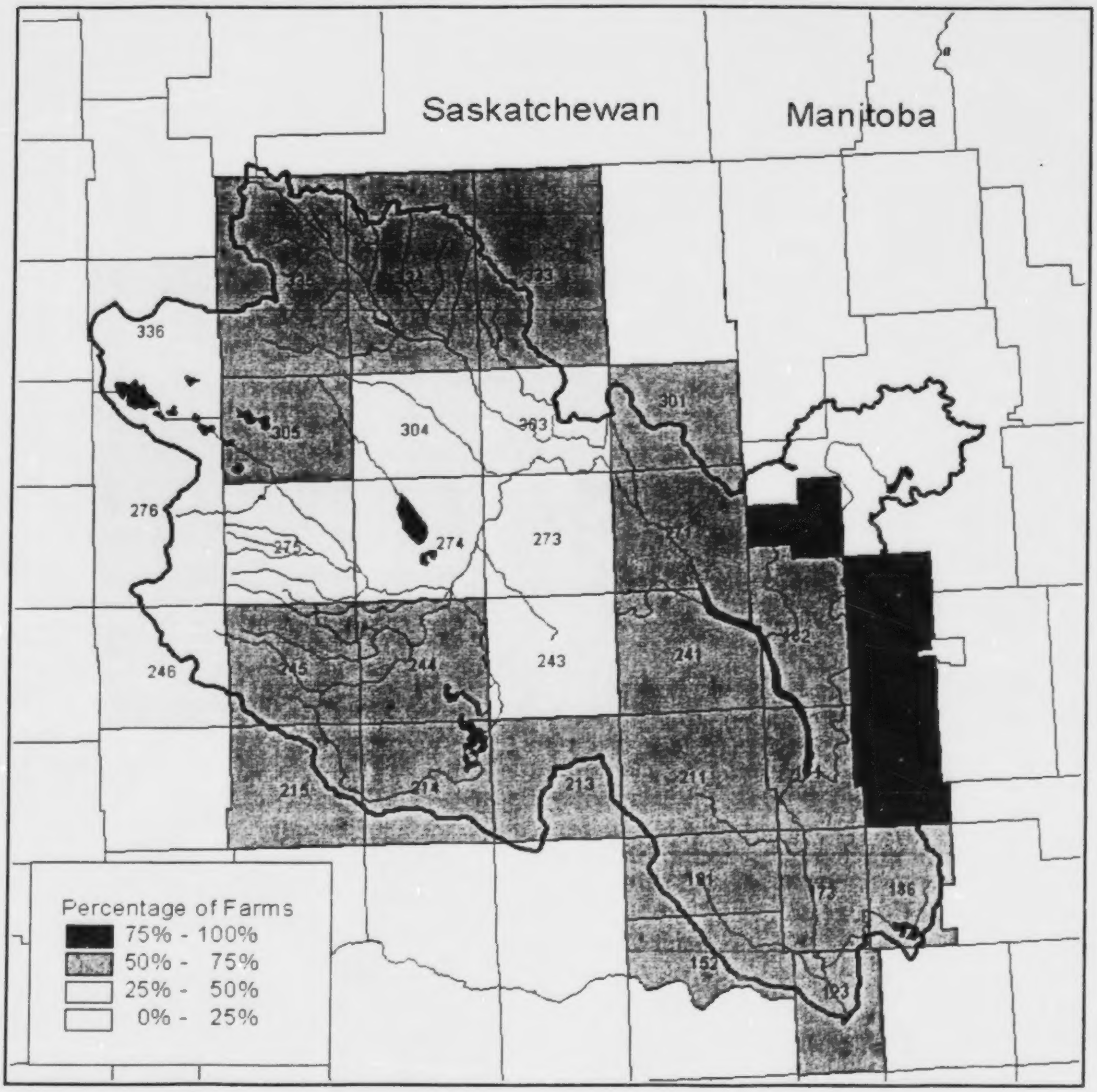
The current hog numbers per rural municipality are in some cases significantly different from those shown on the 1996 census map, due to recent developments (Figure 3.3). A 2400 sow farrow to finish hog unit was constructed in RM #334 during 1998 and initially stocked with animals in January 1999. The total pig numbers (sows, boars, gilts, weanlings and feeders) in the rural municipality will increase by 35,500 animals before 2001.

Similarly, a 5000 sow farrow to finish unit is planned in the general vicinity of RMs #304 and 305. All necessary approvals have been granted for part of the operation which will result in an additional 36,500 pigs in RM #305. Applications are pending (although no specific sites have been chosen at this time) for three remaining feeder barns (tentatively planned for somewhere within the Basin) to complete the project for an additional 34,500 pigs. Other local groups within the Basin have initiated discussions to locate large hog operations within the next several years in their own rural municipalities in the Basin.

In Saskatchewan, as of January 1, 2000, cattle numbers are down 4 percent, hog numbers are up 4 percent, and sheep numbers are up 4 percent from 1999 levels. In Manitoba, as of January 1, 2000 cattle numbers are down 4 percent, hog numbers are down 7 percent, and sheep numbers are up 15 percent from 1999 (Statistics Canada, Livestock Statistics, 1999).

Saskatchewan and Manitoba expect small increases in the cattle inventory over the upcoming years. This increase will not only be in the cow herd, but also in animals kept on feed for market. Both provinces anticipate increases in the hog inventory. Manitoba suggests the hog marketings in the Province may increase by 6 percent in 2000. Saskatchewan anticipates hog marketing to increase by 15 percent in 2000. Broiler chicken production is expected to expand by about 7 percent in Saskatchewan for 1999 (Saskatchewan Agriculture and Food, Annual Report 1998); trends in Manitoba also indicate expansion.

Figure 4.1
Percentage of Farms that have Livestock in the Upper Assiniboine River Basin


Saskatchewan
Manitoba
336
335
333
305
304
303
301
276
275
274
273
246
245
244
243
241
215
214
213
211
181
186
152
123
Percentage of Farms
75% - 100%
50% - 75%
25% - 50%
0% - 25%

56.2% of farms in the Upper Assiniboine Basin have livestock.

Saskatchewan
Agriculture
and Food

10 0 10 20 30 Kilometers
N

Prepared by:	Geomatics Unit, Statistics Branch [RC]
Source:	1996 Census of Agriculture, Statistics Canada (Customized Analysis)
Date:	March 1, 2000

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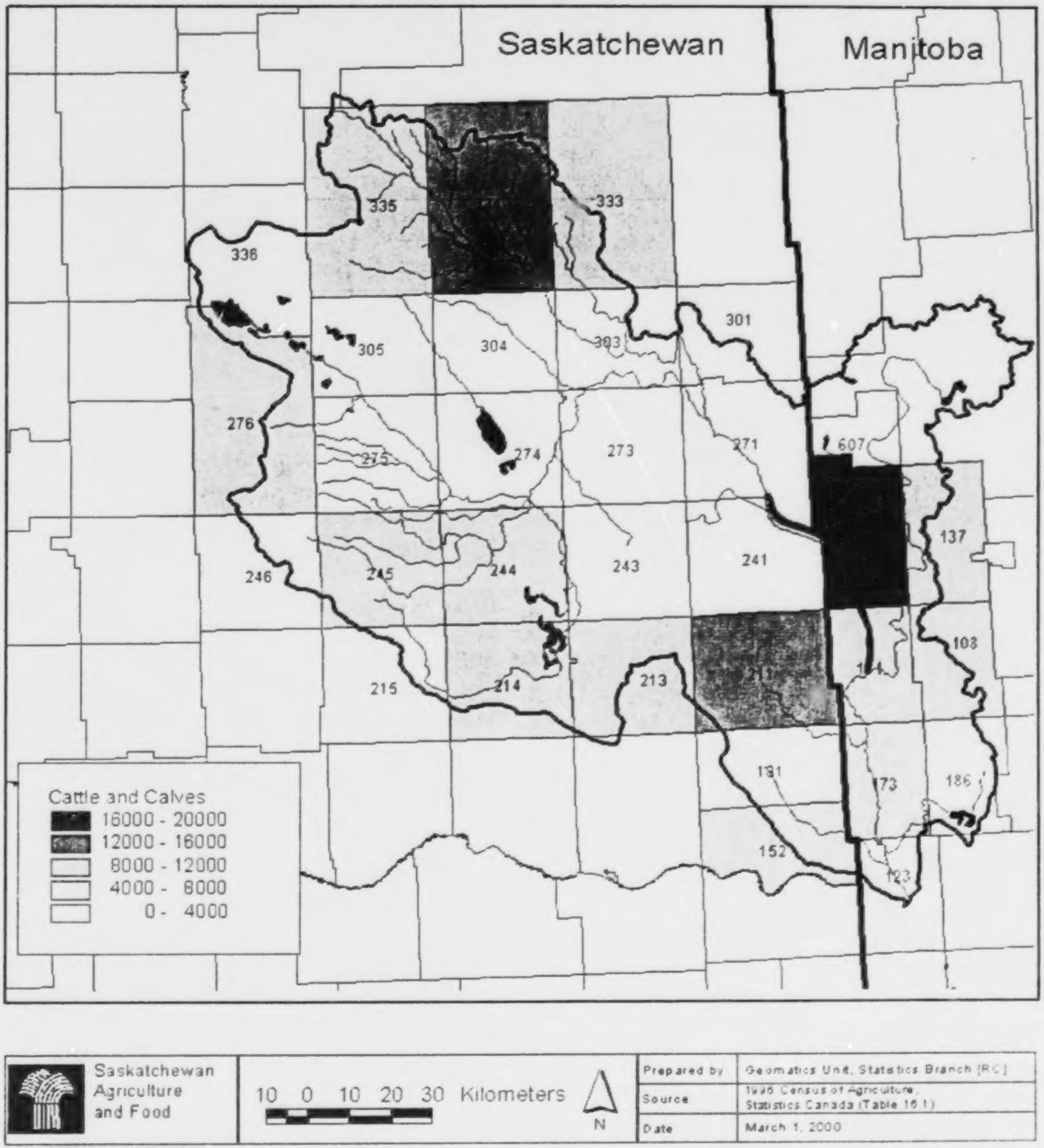
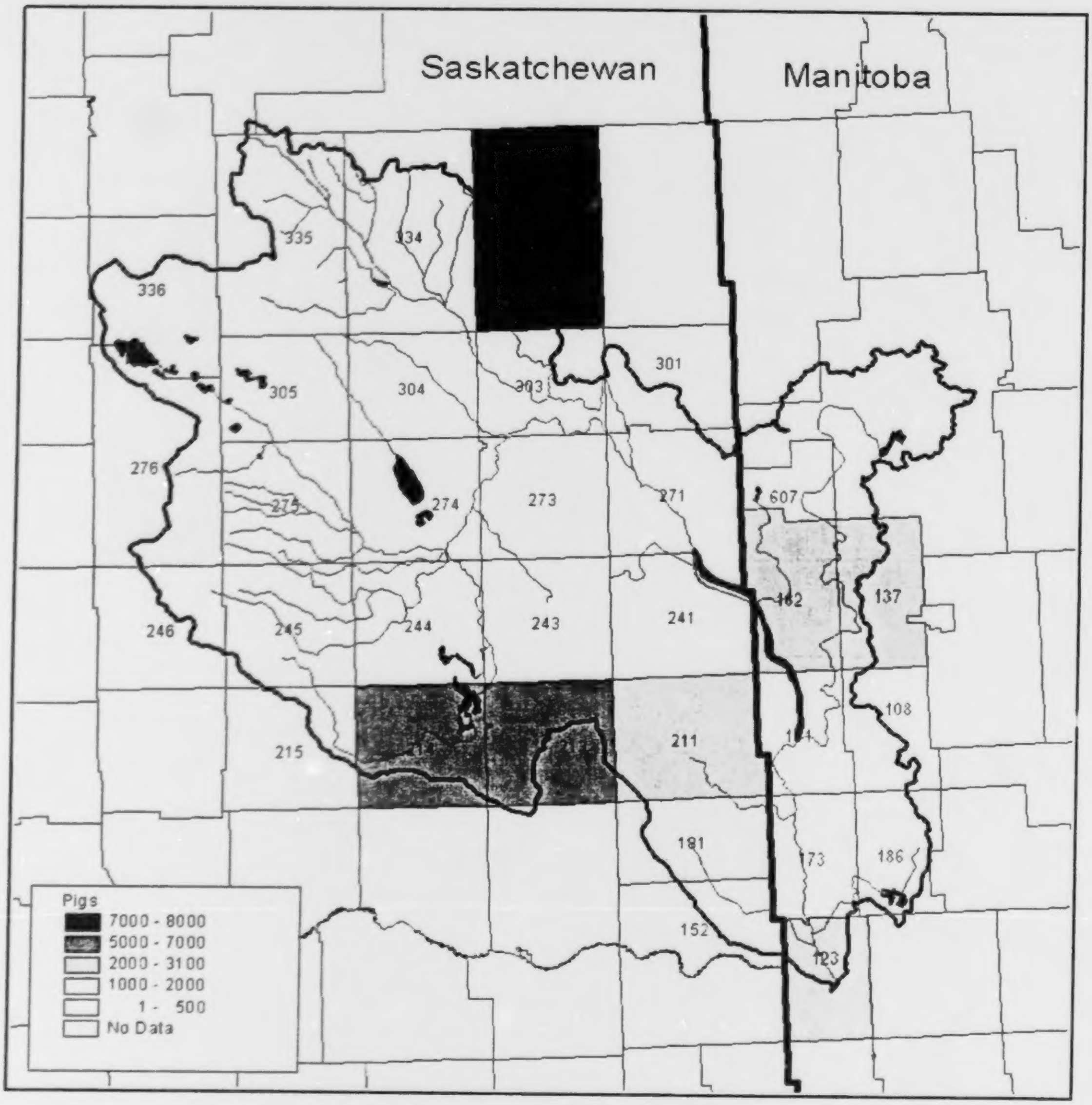
Figure 4.2
Total Cattle and Calves in the Upper Assiniboine River Basin


Saskatchewan
Manitoba
335
333
336
305
304
303
301
276
275
274
273
271
607
137
246
245
244
243
241
108
215
214
213
211
154
181
173
186
152
123
Cattle and Calves
16000 - 20000
12000 - 16000
8000 - 12000
4000 - 8000
0 - 4000
Saskatchewan Agriculture and Food
10 0 10 20 30 Kilometers
N

Prepared by	Geomatics Unit, Statistics Branch [RC]
Source	1996 Census of Agriculture, Statistics Canada (Table 16.1)
Date	March 1, 2000

Copyright © 2000 Government of Saskatchewan

Figure 4.3
Total Pigs in the Upper Assiniboine River Basin


Saskatchewan
Manitoba
335
334
336
305
304
303
301
276
275
274
273
271
607
162
137
246
245
244
243
241
215
211
108
181
173
186
152
123
Pigs
7000 - 8000
5000 - 7000
2000 - 3100
1000 - 2000
1 - 500
No Data

56.2% of farms in the Upper Assiniboine Basin have livestock.

Saskatchewan
Agriculture
and Food

10 0 10 20 30 Kilometers

N

Prepared by:	Geomatics Unit, Statistics Branch [RC]
Source:	1996 Census of Agriculture, Statistics Canada (Table 15)
Date:	March 1, 2000

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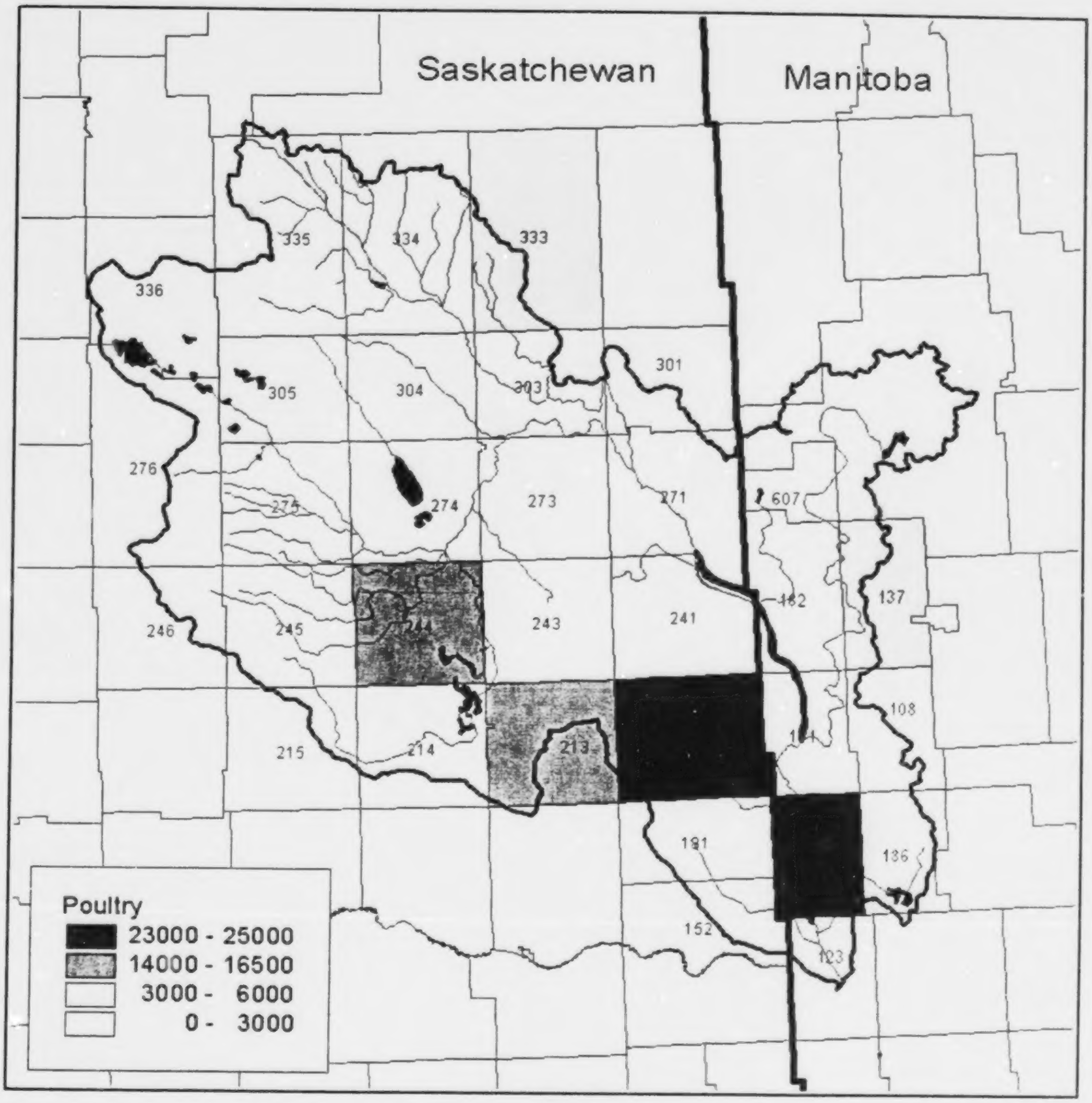
Figure 4.4
Total Poultry in the Upper Assiniboine River Basin


Saskatchewan
Manitoba
335
334
333
336
301
305
304
303
276
275
274
273
271
607
246
245
244
243
241
162
137
215
214
213
184
108
191
186
152
123
Poultry
■ 23000 - 25000
▨ 14000 - 16500
☐ 3000 - 6000
☐ 0 - 3000

56.2% of farms in the Upper Assiniboine Basin have livestock.

Saskatchewan
Agriculture
and Food

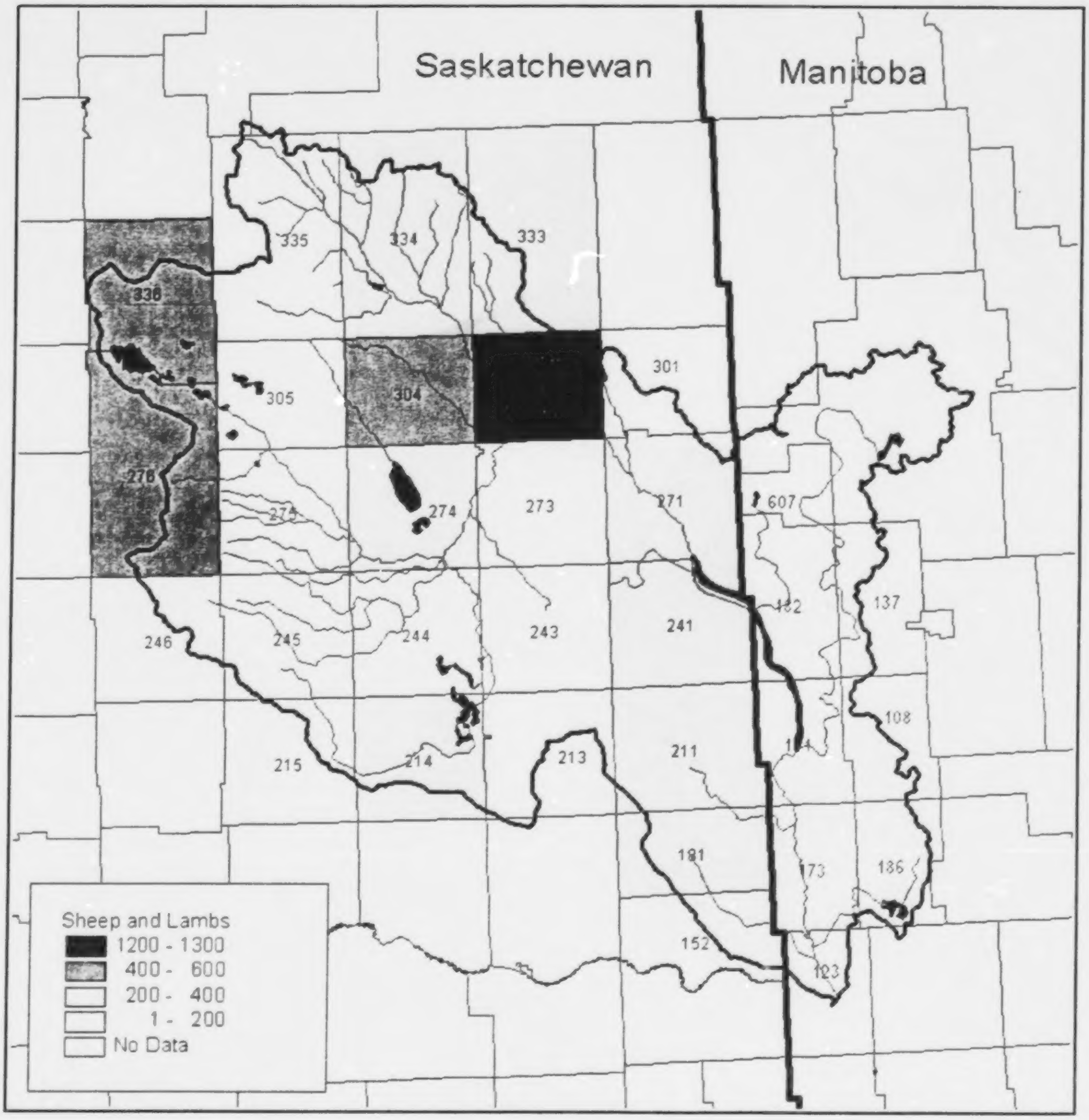
10 0 10 20 30 Kilometers

N

Prepared by	Geomatics Unit, Statistics Branch [RC]
Source	1996 Census of Agriculture Statistics Canada (Table 14)
Date	March 1, 2000

Copyright © 2000 Government of Saskatchewan

Figure 4.5
Total Sheep and Lambs in the Upper Assiniboine River Basin


Saskatchewan
Manitoba
335
334
333
336
305
304
301
276
275
274
273
271
607
137
246
245
244
243
241
108
215
214
213
211
181
173
186
152
123
Sheep and Lambs
■ 1200 - 1300
▨ 400 - 600
☐ 200 - 400
☐ 1 - 200
☐ No Data

56.2% of farms in the Upper Assiniboine Basin have livestock.

Saskatchewan
Agriculture
and Food

10 0 10 20 30 Kilometers

N

Prepared by:	Geomatics Unit, Statistics Branch [RC]
Source	1996 Census of Agriculture, Statistics Canada (Table 16.2)
Date:	March 1, 2000

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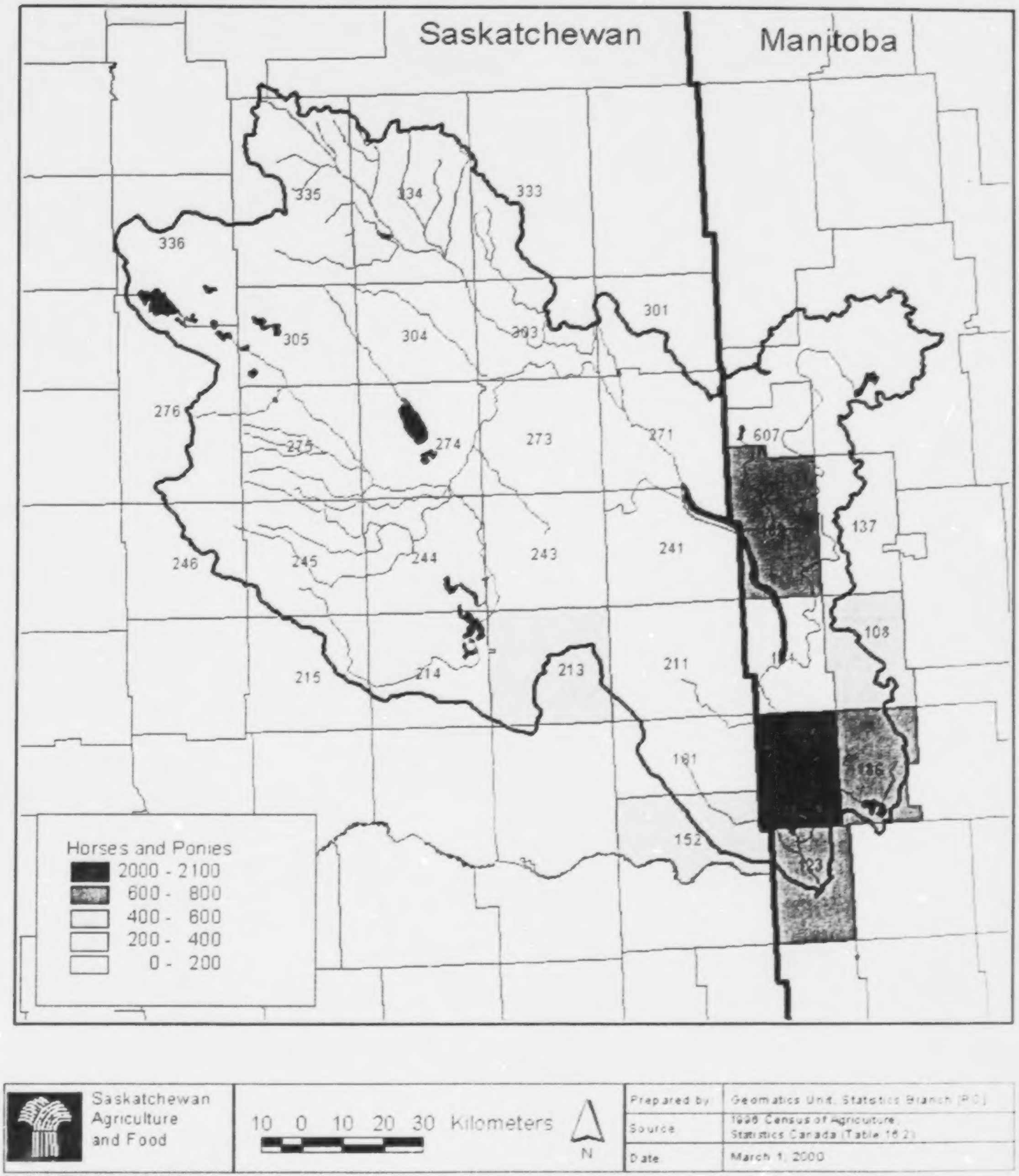
Figure 4.6
Total Horses and Ponies in the Upper Assiniboine River Basin


Saskatchewan
Manitoba
335
334
333
336
305
304
303
301
276
275
274
273
271
607
137
246
245
244
243
241
108
215
214
213
211
161
136
152
123
Horses and Ponies
2000 - 2100
600 - 800
400 - 600
200 - 400
0 - 200
Saskatchewan Agriculture and Food
10 0 10 20 30 Kilometers
N

Prepared by	Geomatics Unit, Statistics Branch (RC)
Source	1996 Census of Agriculture, Statistics Canada (Table 16.2)
Date	March 1, 2000

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Under supply management, the production of milk for domestic use and traditional export markets is controlled by quota allocations. No increase is anticipated in either province. In Saskatchewan, there was a decline in the number of dairies from 700 in 1980 to 400 in 1999, while total quota remained unchanged (pers. comm. Deb Haupstein, Provincial Dairy Specialist, Inspection and Regulatory Management, SAF; March 29, 2000). The trend is to fewer but larger dairy farms.

4.2 Legislation for the Establishment and Operation of Livestock Facilities

Livestock development is regulated in both Saskatchewan and Manitoba, although each province has a somewhat different approach to this regulation.

4.2.1 Saskatchewan

4.2.1.1 *The Agricultural Operations Act*

The Agricultural Operations Act was proclaimed November 27, 1996. In Saskatchewan this Act is the primary legislation that deals with the establishment, expansion, and operation of livestock facilities within the Province.

The main provisions of *The Agricultural Operations Act* include:

- The protection of farmers from unwarranted nuisance lawsuits;
- A mechanism for resolving nuisance disputes between agricultural producers and their immediate neighbors; and
- The protection of groundwater and surface water by proper management of manure and animal waste.

The Agricultural Operations Act consists of two main sections: Part II - Agricultural Nuisance Provisions and Part III - Intensive Livestock Provisions.

- Part II - Agricultural Nuisance Provisions: deals with complaints of nuisance resulting from all agricultural operations, including livestock. More detailed information on the nuisance complaint process and the Agricultural Operations Review Board is available by acquiring a copy of *The Agriculture Operations Act*, the "Guidelines for Establishing and Managing Livestock Operations " publication, or by contacting Saskatchewan Agriculture and Food.

- Part III - Intensive Livestock Provisions: requires operators of certain intensive livestock operations to obtain approved waste storage and waste management plans. Prior to a decision, applications submitted to Saskatchewan Agriculture and Food (SAF) are sent to other departments and agencies for comment. A decision on issuance of an approval is based on information within the application, SAF's own investigation, comments from the referral agencies, and concerns expressed by area citizens. Applications for large intensive livestock operations (ILOs) are routinely sent for comment to Saskatchewan Environment and Resource Management (SERM), Sask Water, Saskatchewan Highways and Transportation, Saskatchewan Municipal Affairs, Culture and Housing, and Saskatchewan Health. Other agencies and organizations may be included at SAF's discretion. The local rural municipality is requested to comment on all ILO application.

4.2.1.2 Approval from Other Authorities

Other agencies may have conditions of approval within their own jurisdiction that can affect the development of livestock facilities. Although these agencies will usually become aware of the proposal through the referral process for application under *The Agricultural Operations Act*, it is always prudent for the livestock developer to contact these groups prior to SAF's referral process to determine what requirements they may have.

1) Local Municipalities may require:
    - Development or discretionary use permits for establishing or expanding livestock operations;
    - Advertising and approval of zoning changes;
    - Input to subdivision approvals (if required) and subdivision servicing agreements;
    - Road maintenance cost agreements for heavy traffic on municipal roads;
    - Building setback distances from roads; and
    - If within a planning district, the recommendation of the planning district.

2) Sask Water may require:
    - A groundwater investigation permit for drilling test wells;
    - Approval to construct and operate wells and use groundwater;
    - Approval to construct and operate earth works and use surface water;
    - Approval to construct within reservoir development areas; and
    - Approval to alter drainage.

3) Saskatchewan Environment and Resource Management may require:
    - Approval if an incinerator is to be used; and
    - Pre-screening under *The Environmental Assessment Act*.

4) Saskatchewan Highways and Transportation may require:
    - Specific setback distances to highways if adjacent to the proposed site.

5) Saskatchewan Health may require:
   - Acknowledgement from the local health district (public health inspector) that the project does not contravene bylaws of the health district.

6) Other agencies may:
   - Be included in the SAF referral process. Typical project specific referral agencies would include railroads, wildlife organizations, regional parks, resorts, towns or villages, community associations, and organized citizen groups.

4.2.2 Manitoba

Several acts share the responsibility for the establishment, expansion, and/or management of livestock facilities in Manitoba (The Agricultural Development Committee,1998). Livestock operators should be aware of a number of provincial acts and regulations and local municipal bylaws that could affect the establishment, expansion, and/or management of their facilities. Siting and other land use considerations are dealt with through *The Municipal Act*. *The Planning Act* and consequent bylaws, permitting and planning authorities are delegated to local municipalities. Water supply may be regulated by *The Water Rights Act*.

Livestock manure and mortalities management are regulated under *The Environment Act*, while odour and other nuisance issues are addressed by *The Farm Practices Protection Act*, and municipal bylaws.

4.2.2.1 *The Environment Act*

Under *The Environment Act*, the *Livestock Manure and Mortalities Management Regulation* MR 42/98 strengthens the protection of the environment, enhances enforcement capabilities, and helps to ensure that livestock production will be sustainable in the long-term in Manitoba.

Following are some important areas addressed under the Regulation:

1) Spreading of manure - land application on fields by large-scale livestock operations, defined as having more than 400 animal units of a given livestock type, is now prohibited from November 10 until April 15. Livestock operations with fewer than 400 animal units of any one type of livestock are exempt, unless their manure management practices are causing an environmental concern. Existing producers have until November 10, 2003 to comply with the new measures concerning winter application of manure, whereas new large-scale producers must comply as soon as their operation is established. Emergency situations may warrant exceptions to the prohibition of winter application, upon approval by Manitoba Conservation. Livestock operations that are otherwise exempt from the prohibition of winter application will still have to meet minimum setback distance requirements from sensitive areas such as watercourses, wells, sinkholes, and springs.

2) Application rate - the Regulation sets enforceable limits on the amount of soil nitrates that can be present in the soil at any point in time. The rate of manure application is to be

determined on the basis of nitrogen content in the manure, residual nitrogen concentrations in the soil, soil texture, and annual nitrogen requirements for the particular crop on that land.

3) Manure management plans - large intensive livestock operations have to prepare and register an annual manure management plan. The manure management plan ensures optimal use of the nutrients in manure and that environmentally sensitive areas can be identified and protected. The manure management plan describes the volume, type (i.e., liquid or solid), and nitrogen content of the manure produced. It also reports how, when, and where the manure will be applied. This new requirement for registration of the annual manure management plan will be in effect starting January 1, 1999 for new operations and November 10, 1999 for existing operations.

4) Manure storage structures - manure has to be stored in appropriate structures. In the case of solid manure, field storage is also acceptable. All structures require a permit from Manitoba Conservation prior to construction. In addition, the structures must be certified by an engineer, before their use or operation, as being constructed according to engineering design standards.

5) Allowance for innovative practices - considerable research and innovation is occurring in the field of livestock production and technological advancements are occurring at a rapid rate. Hence, the requirements of the regulation may be varied where innovative and environmentally sound practices or procedures are proposed.

6) Mortalities - the Regulation provides for proper disposal of mortalities by rendering, composting, incineration, or burial where environmental conditions are suitable. Mortalities shall be stored in a secure manner and kept either refrigerated or frozen if retained more than 48 hours after death.

7) Manure spills - persons transporting livestock manure are required to immediately report the occurrence of a spill or other discharge of livestock manure, as defined in Section 9 of the Regulation, where the location or quantities involved may cause an adverse effect on the environment. Minor spills or spills in locations that do not pose a significant threat or risk to the environment do not need to be reported.

8) Setbacks - siting requirements which establish the minimum distances (100 metres) for which manure storage facilities and composting sites must be set back from surface water courses, sinkholes, wells, and springs, continue to offer strong protection of water resources.

9) Pollution issues - other sections of the Regulation continue to prohibit the direct contamination of surface water and groundwater by livestock manure. Similarly, livestock manure must not be permitted to escape the property boundaries of land where it is either stored or applied as a fertilizer.

4.2.2.2 *The Water Rights Act*

Under *The Water Rights Act*, a license may be required to withdraw water from a surface or below ground source. For agricultural operations, this license is required when water usage exceeds 25,000 litres per day. At lesser rates of usage, no license is required.

4.3 Literature Review- Dillon Consulting Limited: *Upper Assiniboine River Basin Water Quality Study - Final Report, November 1998*

A literature review completed by Dillon Consulting Limited finds that all landscape activities have the potential to impact both groundwater and surface water quality. All land management practices and related farming activities can have a cumulative effect on water quality. Measured degradation or improvements in water quality cannot be easily attributed to any individual practice or activity.

4.3.1 Riparian Areas

Section 3.3 of the literature review completed by Dillon Consulting Limited deals with livestock issues. The report accurately outlines the degradation of riparian areas that can occur when cattle are allowed uncontrolled access to rivers, lakes, sloughs, and streams. However, it is important to note the relative impact of livestock numbers, stocking densities and/or holding concentrations when examining the impacts of livestock on watercourses and riparian areas. Negative effects on water quality and riparian areas can occur with cattle, if animals are not properly managed and distributed (Harker *et al.*, 1997).

- Grazing - increased awareness and adoption of rotational grazing systems, such as time controlled grazing, deferred grazing, and rest rotation grazing systems aids in the distribution of livestock by modifying the placement of animals, varying the duration of grazing in accordance with the landscape's vegetation, topography, and elevation. As well, there is an increasing awareness and participation by more and more livestock producers in adopting effective riparian area management on lands and stream banks within their control.

- Herd Health - improvements to herd health are directly related to improvements in water quality and increased rates of weight gain greatly benefit livestock producers' bottom line. The Whitesand River Watershed Enhancement Project (see Section 4.5.2) is a case in point. Nevertheless, awareness of protection and enhancement of riparian areas needs to be a long-term coordinated effort within the Basin. Individual land managers and livestock operators must be recognized for their efforts in adopting management practices that improve riparian areas.

4.3.2 Field Spreading Manure

On manure utilization, the literature review by Dillon Consulting Limited stresses that manure must be managed as a soil amendment that is applied based on good agronomic practices of testing the soil and the manure and matching nutrient application to the crop being grown. This approach is valid regardless of the size of the livestock operation or species being raised. This approach forms the basis for the manure management strategy within the regulatory framework of each province.

4.3.3 Wells

The literature review makes note that wells with the highest concentrations of nitrates had cattle operations nearby. While the presence of elevated nitrates in groundwater is usually an indication of human activities resulting from animal or human waste, it must be understood that the excess nitrate concentrations may be attributable more to the siting and maintenance of the well than to the cattle. When yard sites were initially developed by the original settlers, one criterion for site selection was the availability of groundwater accessible with a hand dug well. Since pressurized water systems were not available, the cattle were penned very close to the well for convenience. The soil conditions of the cattle pens is then suspect, given the fact such a shallow well could be developed. The accumulation of nutrients from the manure in the pens can be a source of contamination for shallow wells. Hand dug wells are large in diameter, which makes proper sealing of the cribbing against surface water contamination more difficult. The result is that many cattle facilities have been developed more closely to the well (shallow aquifers) than is advisable and on soils that may be questionable by today's standards. The proximity of the household septic system to the well is also a consideration for nitrate contamination.

4.3.4 Well Abandonment

Perhaps the most important point to consider in the literature review by Dillon Consulting Limited, is the discussion on abandoned wells. Any type of excavation that extends into the subsoil increases the potential for groundwater contamination. Improperly abandoned wells are particularly susceptible to providing a direct path for contaminants to reach the groundwater. They can also be a very real safety hazard to animals and people. Existing wells that are improperly capped are equally prone to subsoil contamination. As the report suggests, emphasis on properly decommissioning abandoned wells, in conjunction with assuring operative wells are properly maintained, is of prime consideration for the protection of groundwater in the Basin.

4.3.5 Animal Diseases Associated with Water

The literature review by Dillon Consulting Limited also mentions the transmission of disease when cattle have direct access to open water and flowing water in particular. While several diseases are mentioned in the report, there was no discussion on them. The following information is cited primarily from The Merck Veterinary Manual, 8th Edition (Merck and Co. 1998), with excerpts from other references noted;

- Leptospirosis - is a contagious disease of animals, including man and wildlife. Because the organisms survive in surface waters for extended periods, the disease is often water-borne. The disease in man is often occupationally related to those working frequently with animals. Management methods to reduce transmission include rat control, fencing cattle from potentially contaminated streams and ponds, separation of cattle from pigs and wildlife, careful selection of replacement stock, and vaccination of replacement stock.

- Bovine Viral Diarrhea Virus (BVDV) - is well known to cattle operators. The natural reservoir for BVDV is persistently infected cattle. BVDV is transmitted transplacentally (in the womb) during the first four months of fetal development; therefore, infection is present at birth and lasts for life. Large numbers of BVDV are shed in the secretions and excretions of persistently infected cattle.

- Giardiasis - commonly known as "Beaver Fever" is a parasitic disease that occurs worldwide in most domestic and wild animals, many birds, and people. *Giardia* cysts survive in the environment and thus are a source of infection and reinfection for animals, particularly those in crowded conditions. Cysts are susceptible to desiccation, and areas should be allowed to dry thoroughly after cleaning. Principal animals involved are beaver, porcupines, dogs, and other animals. To prevent the infection in humans, avoid drinking or swallowing any untreated surface water and wash hands after contact with surface water. *Giardia* is now recognized as the most common intestinal parasite in humans world wide and it appears that a similar situation exists in animals (Olson *et al.*, n.d.). It is now established that giardiasis is an important disease of both animals and humans, yet there is limited knowledge of this disease.

- Cryptosporidiosis - is a parasitic disease that occurs worldwide. It is not host-specific and is common in young ruminants, particularly calves. It is also found in man and pigs and is rare in dogs, cats, and horses. Unless the immune system is compromised, it is self-limiting. Principal animals involved are cattle and other animals. To prevent the infection in humans, avoid drinking or swallowing any untreated surface water and wash hands after contact with surface water or direct exposure to cattle and other farm animals.

4.4 Prairie Provinces Committee on Livestock Development and Manure Management

A tri-provincial committee among Alberta, Saskatchewan, and Manitoba was established to develop a common environmental approach for livestock development on the Prairies. The Committee's theme is "Sustainable Livestock Development Through Science Based Standards". The committee realized that each province was dealing with similar concerns regarding livestock issues and that the three provinces were dealing with these livestock issues under similar weather and soil conditions.

The Committee is co-chaired by representatives of Alberta Agriculture Food and Rural Development, Saskatchewan Agriculture and Food, and Manitoba Agriculture and Food. Membership on the Committee includes both regulatory and development based agencies from each province (Alberta Agriculture Food and Rural Development, Saskatchewan Agriculture and Food, Manitoba Agriculture and Food, and Manitoba Conservation). The Prairie Farm Rehabilitation Administration (PFRA) under Agriculture and Agri-Food Canada, represents Canada.

The Committee is responsible for the mandate, direction, selection, and prioritization of specific topics for the development of standards. This is accomplished through regular meetings, consultation with researchers and industry, and detailed priority setting sessions. Topics targeted for standards development are those expected to provide benefit to industry regulators and stakeholders, and which have sufficient scientific basis for development. Topics lacking in sufficient science for the development of standards are identified as priority research topics.

For the 1999-2000 period, the Committee has formed four working groups to draft standards for:

- Site characterization for livestock development;
- Manure storage construction;
- Manure use and application; and
- Defining animal units.

Completion dates of the tasks will vary between topics. Most tasks are targeted for completion in the year 2000. Communication of committee activities is accomplished through stakeholder consultation and through an annual manure management conference. The conference highlights advanced and applied research relating to manure management with a prairie theme, and is hosted on a rotational basis by the three prairie Provinces. The first manure management conference was held on June 23 and 24, 1999 in Saskatoon, Saskatchewan. The year 2000 conference is scheduled for June 26 to 28 in Calgary, Alberta.

4.5 Demonstration Projects

4.5.1 Off-Stream Livestock Watering Demonstration

The Water Quality Committee of the Upper Assiniboine River Basin Study assisted in developing an off-stream watering demonstration at the PK Hereford farm on the Whitesand River south of Canora on Hwy. No. 9. Research in Alberta and Saskatchewan has shown that livestock performance has benefitted from clean drinking water (Willms *et al.*, n.d.). Given a choice, the research showed that cattle preferred to drink from a trough rather than from a dugout. The daily rate of gain can be significantly greater for cattle using a trough as compared to those accessing surface water directly. Similar research is continuing in the Prairie provinces and British Columbia.

Based on the economic benefits and increasing environmental concerns of the public, herd and range management practices now focus on techniques that protect or enhance water quality by restricting livestock access to surface water supplies. These techniques tend to encourage vegetative growth in riparian areas. An increase in the numbers of woody plants improves stream bank stability and eventually offers better shelter for the cattle. The increased plant growth and stability of the stream bank leads to healthier and more diverse aquatic life in the stream or river.

4.5.1.1 1998 Activities

In the spring of 1998, PK Herefords approached Saskatchewan Agriculture and Food to discuss alternatives to the pasturing and overwintering system they currently practice. The Whitesand River flows in a northerly direction through the east portion of their pasture. From the west, the Good Spirit Lake drainage channel dissects the section and joins the Whitesand River. PK Herefords wanted to move the wintering site from the river's edge to an upland area north and west of the main yard. The Upper Assiniboine River Basin Study, Water Quality Committee, became involved and supported their plans. The Committee suggested that an off-stream watering system be used over the summers of 1998 and 1999 as a trial to determine the practicality of fencing along the banks of the Whitesand River. With the local support of the District 19 Agriculture, Development, and Diversification Board (ADD Board), the operator agreed to the plan and the project was initiated. A solar powered 24-volt pumping unit was installed to deliver water from the Whitesand River to a trough on the edge of the river bank. Two 12-volt marine batteries powered both the pump and electric fence. About 2.5 kilometres of electric fence was installed along both sides of the river to restrict the cattle from watering in the river. River crossings for the cattle were established by placing gates in the electric fence on either side of the river at several locations. It took two days to place the electric fence along both sides of the Whitesand River. The fence was energized as each section was completed and marked with ribbon. By the time fence construction was finished, the cattle had been trained to the fence and were remaining out of the area between the fence and the river. The fence was in place and operational before the solar pumping system was installed. The solar powered watering system was not received and installed until September. The cattle never used the trough for their water supply. Lack of use of the trough by the cattle was attributed to several factors:

- The solar pump/trough system was not in place long enough for the cattle to adapt;
- The river should have been completely isolated for a period of time to force the cattle to drink from the trough; and
- Although placed in the near vicinity of the mineral/salt blocks and back rub, the trough should have been placed immediately adjacent to these items.

Fencing of a water course is not always the practical answer to riparian area protection. In this pasture the Whitesand River's flood plain is relatively wide and shallow. It is prone to flooding in the spring and has variable water depth throughout the summer and fall due to rainfall occurrences and upstream water management. A heavy rain in June 1998 raised the water level of the river sufficiently to flood sections of the electric fence. Although the fence withstood the onslaught of water and debris very well with only minor repair necessary after the water went down, it demonstrated that corridor fencing for this site was not a long-term solution.

A more practical approach is required on a river with such a wide and low flood plain. Adopting a rotational grazing system, whereby the cattle are allowed to intensively graze the area for a very short time period and are then moved off to another pasture may be the solution. This type of system works well for grazing in the fall when water levels are usually at the lowest and forage supplies elsewhere in the pastures are declining. In October 1998 the fence and watering system were removed from the river area.

4.5.1.2 1999 Activities

The solar powered pump and watering system were re-installed in the pasture in the spring of 1999. No additional fencing was installed. The cattle were given free choice to water from either the river or a trough. As stated earlier, research has shown that cattle prefer to water from a clean trough rather than a static water source which they must enter to drink (i.e., a dugout or slough). The demonstration was intended to confirm whether cattle also exhibit this preference with flowing water. Flowing water tends to experience less quality degradation than standing water. Over the years the cattle herd had become very accustomed to drinking from the river. To help offset this habit, the watering trough was located adjacent to the mineral/salt blocks and back rub as an added incentive to use the trough.

The cattle did exhibit some tendency to drink from the trough instead of from the river. Not all animals used the trough. This was expected given the animals' past history of always having had the river as the only source of water. The pumping system was removed in the fall of 1999 and the project was terminated.

4.5.2 Whitesand River Watershed Enhancement Project

In addition to PK Herefords, five other cattle operators on or near the Whitesand River were approached to determine if they wished to improve their riparian area management along the river and its tributaries. Several meetings were held with all interested co-operators. It was explained that in conjunction with improvements to the riparian areas, application would be initiated under *The Agricultural Operations Act* to have the confinement portion of each of their livestock operations renovated sufficiently to receive approval under the Act. All agreed to participate and riparian area/pasture management plans were developed.

Application was made to the National Soil and Water Conservation Program (NSWCP) for support funding. All management plans were developed to target two primary purposes:

- Voluntary adoption and demonstration of alternative livestock and cropping management practices to protect or enhance water quality in riparian areas; and
- Cattle confinement area renovations necessary to receive approval under *The Agricultural Operations Act.*

The Whitesand River Watershed Enhancement Project was patterned after a similar and relatively successful riparian management project near Melville called the Crescent Creek Watershed Enhancement Project. In 1997, plans were made to enhance landowners' awareness of riparian management practices and water quality issues on Crescent Creek upstream of the City of Melville Reservoir. The reservoir, in addition to supplying a portion of the City of Melville's municipal water supply, is a recognized sport fishery, one of the few sites in eastern Saskatchewan annually stocked with pickerel from the provincial fish hatchery.

Approximately 70 landowners within the targeted watershed area were contacted, provided information about riparian area management and surveyed as to their interest in participating in the project. Site visits were conducted with interested landowners and riparian management plans were developed and voluntary agreements to undertake enhancement activities were completed. To date, 12 co-operators have undertaken various enhancement activities and 2,880 acres of land have been impacted upstream of the reservoir.

The adoption of riparian enhancement activities was found to be greater in the second year of the project than the first and this was attributed to three factors:

- Time required to "plant the seed" or idea of change;
- Neighbor watching neighbor and learning from their peers; and
- Overcoming a watershed project's negative connotation of land control.

It is anticipated that future participation by landowners will be limited only by budget, as most producers are environmentally conscientious and want to adopt enhancement activities, but cannot due to currently depressed economics in the primary agricultural production sector.

In addition to working with landowners, a group of local volunteers from the Melville Comprehensive Institute and wildlife conservation groups were trained to assist with volunteer ecological monitoring of Crescent Creek. This has involved educational workshops (three held to date), and monthly monitoring of water quality, riparian health assessment of various reaches of stream banks along Crescent Creek, and surveys of macro-invertebrates. Water samples are collected at three sites each month and analyzed for temperature, pH, dissolved oxygen, electrical conductivity, total dissolved solids (TDS), nitrates, phosphates, and coliform bacteria. The riparian health assessment criteria used were developed by Dr. Paul Hansen, Riparian and Wetland Research Program, Montana State University. The Crescent Creek project was made possible by in-kind contributions from participating landowners and funding from Environment Canada's Action 21 Program (1998-2000), the Canadian Adaptation in Rural Development in Saskatchewan Program (CARDS, 2000-2001), and the efforts of partnering agencies of PFRA, SWCC, and SERM.

In the spring of 1999, funding support was confirmed for the Whitesand River Watershed Enhancement Project for activities related to landowner contact, riparian area enhancement, and volunteer ecological monitoring. Initially, over 127 landowners were contacted along a 56.3 kilometre target section of the Whitesand River, within rural municipalities #273, #274, and #244. The project was intended to educate and increase awareness of riparian management practices and explain the benefits of stream bank stewardship. By August 1999 riparian management plans were developed for a total of eight co-operators, involving 3,840 acres. All six co-operators have cattle near the Whitesand River or a tributary of the Whitesand River.

Numerous activities were undertaken by the project co-operators throughout the spring, summer, and fall of 1999. These activities included establishment of vegetative buffer strips, conversion of crop land to forages, fence construction, off-stream watering site development, berm construction (to control runoff), improvement of low-level crossings, rotational grazing management planning, and the relocation of winter feeding sites. Enhancement activities were cost-shared with the landowners to a maximum of 50 percent as described below.

4.5.2.1 PK Herefords (Clint, Jim, and Richard Kopelchuk)

The Kopelchuks currently operate a mixed farming operation involving over 1000 acres of grains and oilseed production, and a 60-head purebred Horned Hereford operation along the banks of the Whitesand River on NE-23-29-04-W2 in the RM of Good Lake #274. Their farm is situated adjacent to Hwy No. 9 where the highway crosses the Whitesand River south of Canora, Saskatchewan. Upland soils are dominantly sandy fluvial (Perley-Meota) and the lower flood plain areas are weakly developed runway soils associated with shallow, poorly drained areas. Their existing wintering facilities and holding pasture are located beside the Whitesand River within the flood plain.

The Kopelchuks' riparian management plan was to relocate the winter feeding site to an upland area west of the yard and away from the Whitesand River. A multi-row shelter belt was established in 1994 around the perimeter of the new winter feeding site to provide additional shelter. Relocation in 1999 involved constructing 152 m of corral fence, 152 m of porosity fence, barbed wire fence, relocating the cattle shelter, trenching 122 m of water and power lines, and installing two watering bowls west of their existing farm yard. Decommissioning of the old winter feeding site and additional tree planting on the south perimeter of the quarter section are planned in 2000. Approval under *The Agricultural Operations Act* was received in fall 1999.

Project Cost: $28,542.00

4.5.2.2 Lucky "C" Ranches (Al Claiter)

Al Claiter operates a 100-head purebred cattle operation west of Ebenezer in the RM of Good Lake #274. Five out of six quarters of land (E1/2-32-27-04-W2, S1/2-33-27-04-W2 and SW-27-27-04-W2) are bisected by Yorkton Creek, a tributary of the Whitesand River, and are located just south of the convergence of the Yorkton and Cussed creeks. The Town of Ebenezer well is located on his home quarter (SE-32-27-04-W2).

Claiter's riparian management plan was to construct 8 km of fence (permanent and electric) to restrict access of livestock to the creek and other surface water bodies. Vegetative buffer strips were established along 3.2 km of stream bank, an additional 60 acres of crop land was converted to forages, and two of three off-stream watering sites were established. Mr. Claiter received approval under *The Agriculture Operations Act* in the fall of 1999.

Project Cost: $12,911.00

4.5.2.3 Weinbender, Carey and Leanne

The Weinbenders operate a mixed grain and 80-head purebred Charolais operation on six quarters of land in the RM of Sliding Hills #273. Five of the six quarters are bisected by the Whitesand River and land use is predominantly forage production (hay and pasture). In the past, the Weinbenders' rotational grazing system utilized the riparian areas and stream banks extensively, and the cattle watered directly from the river. The Weinbenders enhanced their present rotational grazing system and converted an additional 100 acres of crop land on an adjacent upland site to forage to reduce the grazing pressures on the riparian areas. This was accomplished by seeding additional acres of crested wheatgrass and meadow bromegrass on two parcels (NW-30-29-03-W2 and SE 31-29-03 W2), constructing a barbed wire fence, and establishing an off-stream watering site.

Their winter feeding site built on the south facing slope of a shallow coulee on SW-31-29-03-W2, is less than 200 metres from the Whitesand River. It consists of five holding pens, a 12 by 24 metre cattle shelter, calf shelters, lights and watering bowls. The coulee bottom or draw area has extensive woody vegetation running approximately 350 m in length, and flows intermittently (for 2-10 days each spring) into the Whitesand River. Peak surface runoff through the coulee is largely attributed to spring snow melt entering the ditches of the grid roads that run west and north of, and from beyond their farmyard. This ditch runoff then drains easterly through a ditch culvert and into the coulee. The south-facing orientation of the winter feeding site provides for high rates of sublimation, and surface runoff directly from the winter feeding site in spring is minimal. Significant rainfall events in spring/summer are the greatest potential source of surface runoff from the winter feeding site but by then the cows and calves have already been turned out onto pasture. Each year the cattle are normally turned out to crested wheatgrass (CWG) pastures in early spring (May) and do not return to the winter feeding site until November/December.

The Weinbenders originally planned to relocate their wintering facilities to an upland area on NE-25-29-04-W2, 300 metres west of the existing yard site, approximately 366 m away from the river. Despite receiving NSWCP approval to fund 50 percent of their original proposal, the economic feasibility of relocation, combined with current economic constraints, eliminated the possibility of relocation. The Weinbenders strived to become compliant with *The Agricultural Operations Act* and a revised riparian management plan was proposed, involving PFRA engineered options such as culvert and drop structures and holding ponds. Again, cost estimates for the engineered works were excessive (over $40,000) and prohibitive. Also of note, the loss of native woody vegetation due to proposed construction activities and earth moving equipment would have been extensive and required considerable time for rejuvenation. Finally, site assessment of the coulee in August 1999 revealed extensive natural re-vegetation (i.e., grassed in) of the coulee bottom, after an electric fence was installed running parallel to the bottom of the coulee. This left the cattle to the higher side slopes and upland areas of the winter feeding site and away from the bottom of the draw area. Additional measures of manure management and corral cleaning were imposed and the site was finally granted approval under *The Agricultural Operations Act* in February 2000.

Project Cost: $12,911.00

4.5.2.4 Lamont, Tom and Betty

The Laments operate a 25-head livestock operation on 62 acres on Pt-SW-28-30-03-W2, which is bisected by the Whitesand River, in a highly visible location immediately adjacent to Hwy No. 5 east of Canora. Soils are dominantly silty clay loam (Naicam-Yorkton) with some sandy loam (Bredenbury-Meota) occurring. The parcel is separated into five grazing paddocks of native and tame forage, of which three paddocks include riparian areas. The river banks of the Whitesand River are deeply incised at this location. In the past the cattle grazed on the steep slopes down to the water's edge and watered from the river. The Laments wanted to mitigate the stream bank erosion that was evident from this practice.

The Laments' riparian management plan focused on enhancing the riparian condition by deferring and limiting the duration of grazing on the river banks. This was accomplished by the establishment of an off-stream watering site, rejuvenating the upland forage stand, and construction of approximately 800 metres of barbed wire fence. As well, an old domestic garbage dump site which was situated within the riparian area, and visible from Hwy No.5, was removed and the site reclaimed. The Laments received approval under *The Agricultural Operations Act* in the fall of 1999.

Project Cost: $3,583.00

4.5.2.5 Manahan, Ward and family

Ward Manahan and his family operate a mixed farm along Hwy No. 9 south of Canora on the N1/2-24-29-04 W2. Approximately 1.4 km of Whitesand River bisects the NW quarter. The soils are dominantly sandy fluvial (Perley and Perley-Meota). Current land use on the 320 acres includes:

- pasture along a narrow strip of river bank;
- 30 acre paddock seeded to smooth brome/alfalfa in 1997 and 1998 (some re-seeding was required due to dry conditions and poor establishment);
- 30 acres seeded to alfalfa for hay;
- approximately 170 acres cultivated; and
- 90 acres of yard, gravel pits and river bank.

Manahans' riparian management plan was to implement a rotational grazing system that deferred grazing of his 30 head of cow-calf pairs on the river banks. To accomplish this, vegetative buffer strips were seeded along the river, 80 acres of crop land was converted to pasture, 4 km of barbed wire fence were constructed to restrict access of cattle to the river, and an off-stream watering site was established. The Manahans received approval under *The Agricultural Operations Act* in the fall of 1999.

Project Cost: $14,884.00

4.5.2.6 Pretty View Stock Farm, (Ivan and Phyllis Olynyk)

Ivan and Phyllis Olynyk run a 100-head purebred Red Angus operation in a highly visible location along Hwy No. 9 within 300 metres of the Whitesand River. The soils are dominantly sandy fluvial (Perley and Perley-Meota soils). Their existing winter feeding site on Pt. SE-13-29-04-W2 is situated on (and bisected by) an intermittent creek (tributary of the Whitesand River).

Their riparian management plan involved relocating the winter feeding site to an upland area away from the creek and relocating corrals and porosity fence, calving sheds and watering bowl. The management plan also included the construction of a 800 metre berm, improving a low level crossing and culvert installation, grassing a buffer strip and the berm, and constructing approximately 1.6 km of barbed wire fence along the perimeter of the creek to restrict access of the cattle to that area. On W1/2-12-29-04-W2, the Olynyks were also interested in improving a 30-acre riparian pasture dissected by Wallace Creek. Wallace Creek is a tributary of the

Whitesand River which crosses the Hwy No. 9. Cattle currently water directly from the creek. Time constraints did not allow the work on the riparian pasture to be completed in 1999.

Project Cost: $16,792.59

Local groups and educational institutions were approached to determine interest in assisting with water quality monitoring, riparian health assessment, and macro invertebrate surveys. At six sites along the Whitesand River and its tributaries, water samples were collected and analyzed, macro invertebrates were surveyed and specimens were collected. Song bird and waterfowl surveys were conducted.

Funding under the NSWCP was also approved for production of a 22-minute video featuring riparian projects within the Basin and across Saskatchewan. The video is being prepared by the project partners for general distribution to explain the merits of good riparian area management from producers' standpoints. Entitled "Riparian Areas: Caring for a Prairie Treasure", this video will be available for general distribution in April 2000 and will provide an excellent educational tool for schools, producer groups and public extension events and promote the efforts of the land owners involved in stream bank stewardship.

A full size display featuring the Whitesand River and Crescent Creek Watershed Enhancement Projects was developed in the fall of 1999. The display helped promote project accomplishments at the "Where Land Meets Water" Riparian Conference in Red Deer, Alberta during October 19-21, 1999. The display was also used at the Forage and Grazing Management Conference in Saskatoon, Saskatchewan in December 8-10, 1999 and at the Farm and Leisure Trade Show in Yorkton, Saskatchewan April 27 - 29, 2000.

Other livestock producers along the Whitesand River and tributaries have expressed interest in improving the riparian areas in 2000. Funding from Canadian Adaptation in Rural Development in Saskatchewan Program CARDS (2000/2001) will assist in this endeavour.

4.6 Summary and Recommendations

Based on the observations in the Dillon Consulting Limited report "Upper Assiniboine River Basin Water Quality Study - Final Report, November 1998" and the UARBS's research of the Basin, several key points that should be targeted by and for the livestock industry with respect to improving water quality were noted.

4.6.1 Key Target Areas for Livestock Industry

1) Proper decommissioning of abandoned wells; proper maintenance of existing wells and; proper siting and construction of new wells.

2) Improvement to riparian areas through alternative pasturing, livestock watering systems, and properly located and managed winter feeding sites.

3) Increased awareness of the value of manure as a resource rather than a waste, and the related manure management practices associated with storage, removal and land application.

4) Education to the public that proximity of animals, confined or pastured, near surface water does not automatically mean pollution is occurring.

5) Long-term monitoring of water quality and riparian health on a watershed basis; utilizing well defined parameters and protocols along with efficient implementation, for establishing baseline information, analyzing emerging trends or issues, and planning/developing practical, targeted solutions and recommendations.

6) Education and awareness of issues affecting landscape management (i.e., land and water) involves an integrated interagency approach to strive for the provision of accurate, unbiased, and effective communication of information/results to the general public and stakeholders.

4.6.2 Public Information

A brochure and fact sheet were prepared as part of a public information program and are in Appendix V of this report. In the 18 page booklet entitled "Water Quality in the Upper Assiniboine River Basin", an overview of livestock and water quality was provided on pages 9 to 11. In addition, a fact sheet was developed on the Kopelchuk Project; "Off-Stream Cattle Watering Demonstration Site".

5 Cropping and Water Quality

5.1 Introduction

Annual cropping is practiced by virtually every farm in the Basin. This chapter offers discussion on tillage practices, fertilizer use, and associated regulatory controls.

Figures 5.1 to 5.4 are maps of the Basin that were developed based on data from the 1996 Census of Agriculture. Figure 5.1 shows the tillage practices used to prepare land for seeding, while Figures 5.2, 5.3, and 5.4, respectively, show fertilizer, herbicide, and insecticide usage in the Basin. The figures show that commercial fertilizers and herbicides are used extensively throughout the Basin. Insecticides are less commonly used. The need for insecticides is dependent upon whether weather conditions support above normal proliferation of harmful insect pest outbreaks.

The maps only show the agricultural use of herbicides, insecticides, and fertilizers. The maps do not include the products used in non-agricultural sectors such as residential lawns and gardens, parks, golf courses, or forestry.

5.2 Pesticides

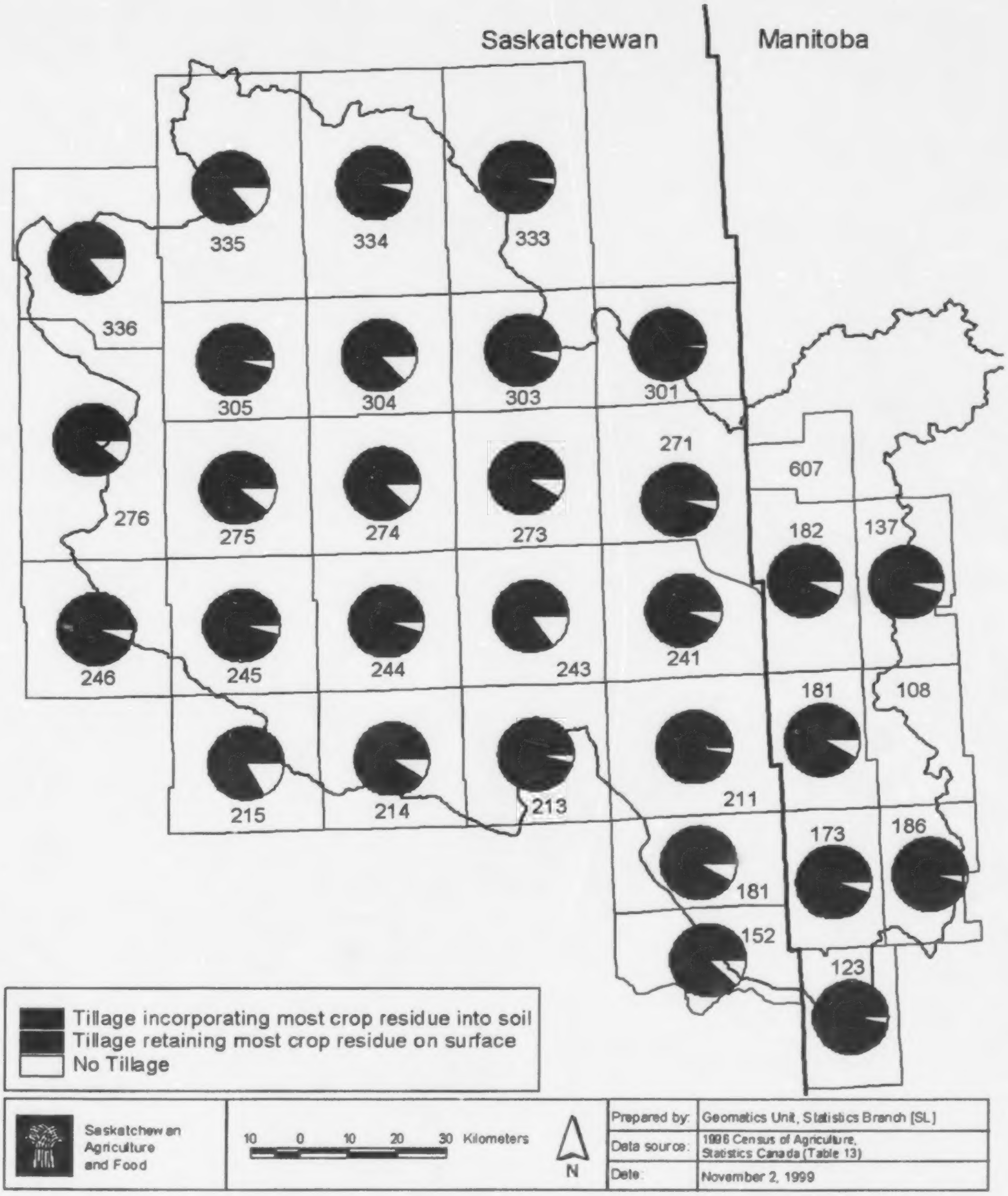
5.2.1 Pesticide

A pesticide is any chemical used to control pests such as weeds (herbicides), insects (insecticides), crop diseases (fungicides), or rodents (rodenticides). In general, insecticides are more toxic than herbicides. Organophosphorous insecticides are more toxic than carbamates and organochlorine insecticides. Pesticides are classified in three ways:

5.2.1.1 Pesticide Classification by Purpose/Mode of Action

(1) Insecticides
(a) contact insecticides - direct external contact with insect provides control
(b) stomach poisons - insect must ingest to provide control
(c) systemic insecticides - applied to and absorbed by plant/animal for insect control
(d) fumigants - contact and control insect through vaporized form; this type can be further classified by the stage of life cycle that the insect is currently in during control: adulticides, larvicides, ovicides

Figure 5.1
Tillage Practices Used to Prepare Land for Seeding in the Upper Assiniboine River Basin


Saskatchewan
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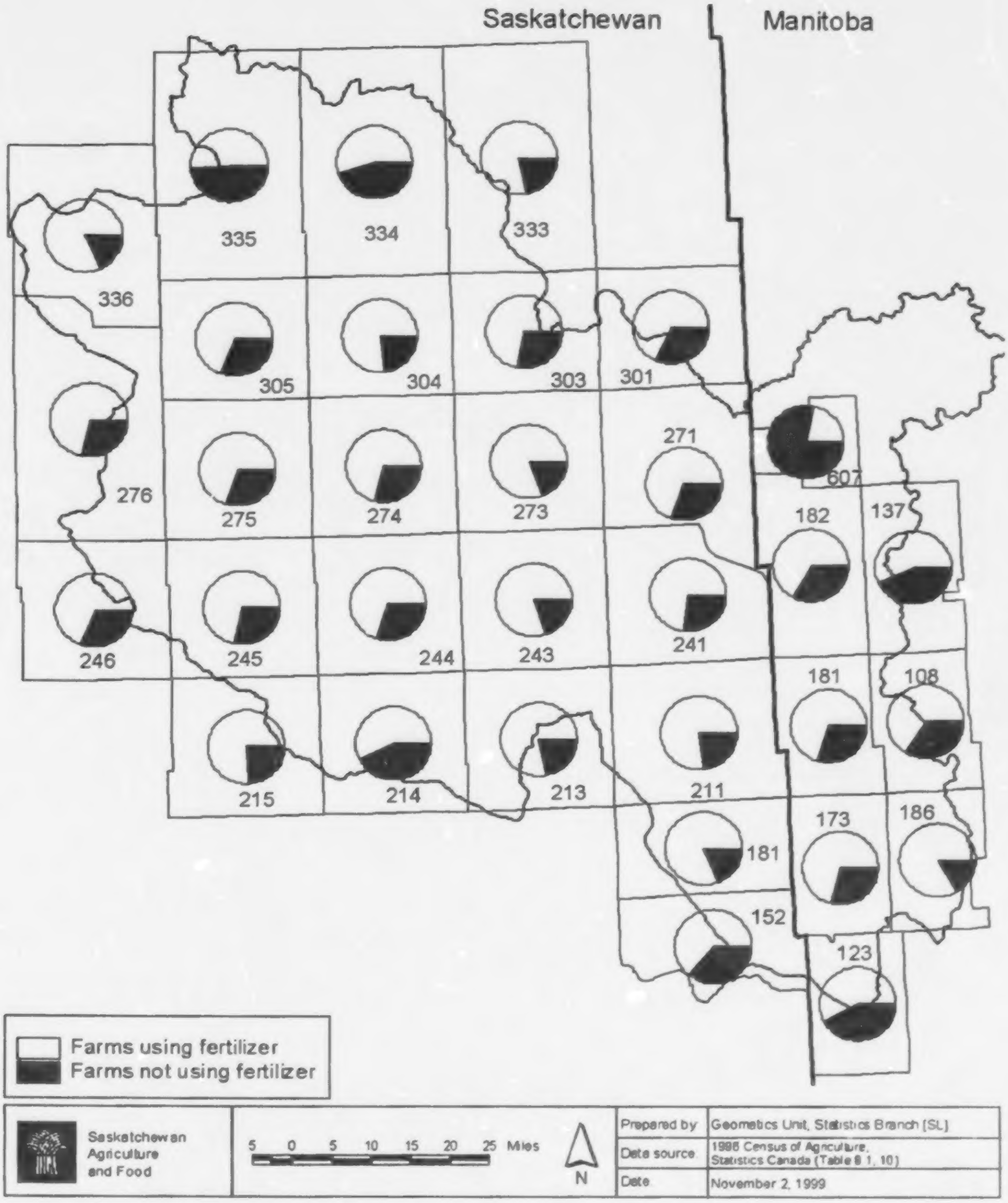
271
607
182
137
246
245
244
243
241
181
108
215
214
213
211
173
186
181
152
123
Tillage incorporating most crop residue into soil
Tillage retaining most crop residue on surface
No Tillage
Saskatchewan Agriculture and Food
10 0 10 20 30 Kilometers
N
Prepared by: Geomatics Unit, Statistics Branch [SL]
Data source: 1996 Census of Agriculture, Statistics Canada (Table 13)
Date: November 2, 1999

Figure 5.2
Fertilizer Usage in the Upper Assiniboine River Basin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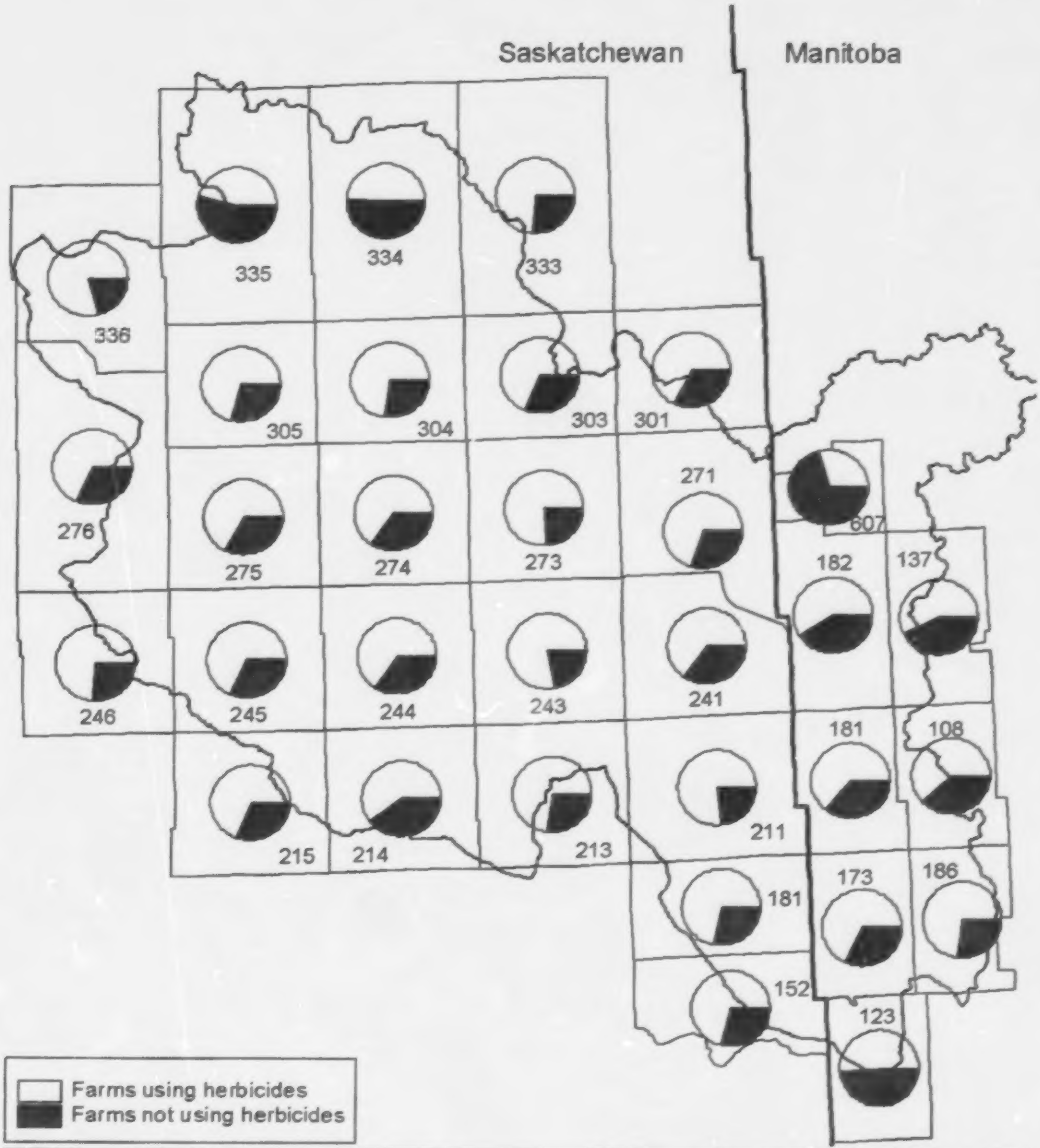
181
173
186
152
123
Farms using fertilizer
Farms not using fertilizer
Saskatchewan Agriculture and Food
5 0 5 10 15 20 25 Miles
N

Prepared by	Geomatics Unit, Statistics Branch [SL]
Data source	1996 Census of Agriculture, Statistics Canada (Table 8 1, 10)
Date	November 2, 1999

Figure 5.3
Herbicide Usage in the Upper Assiniboine River Basin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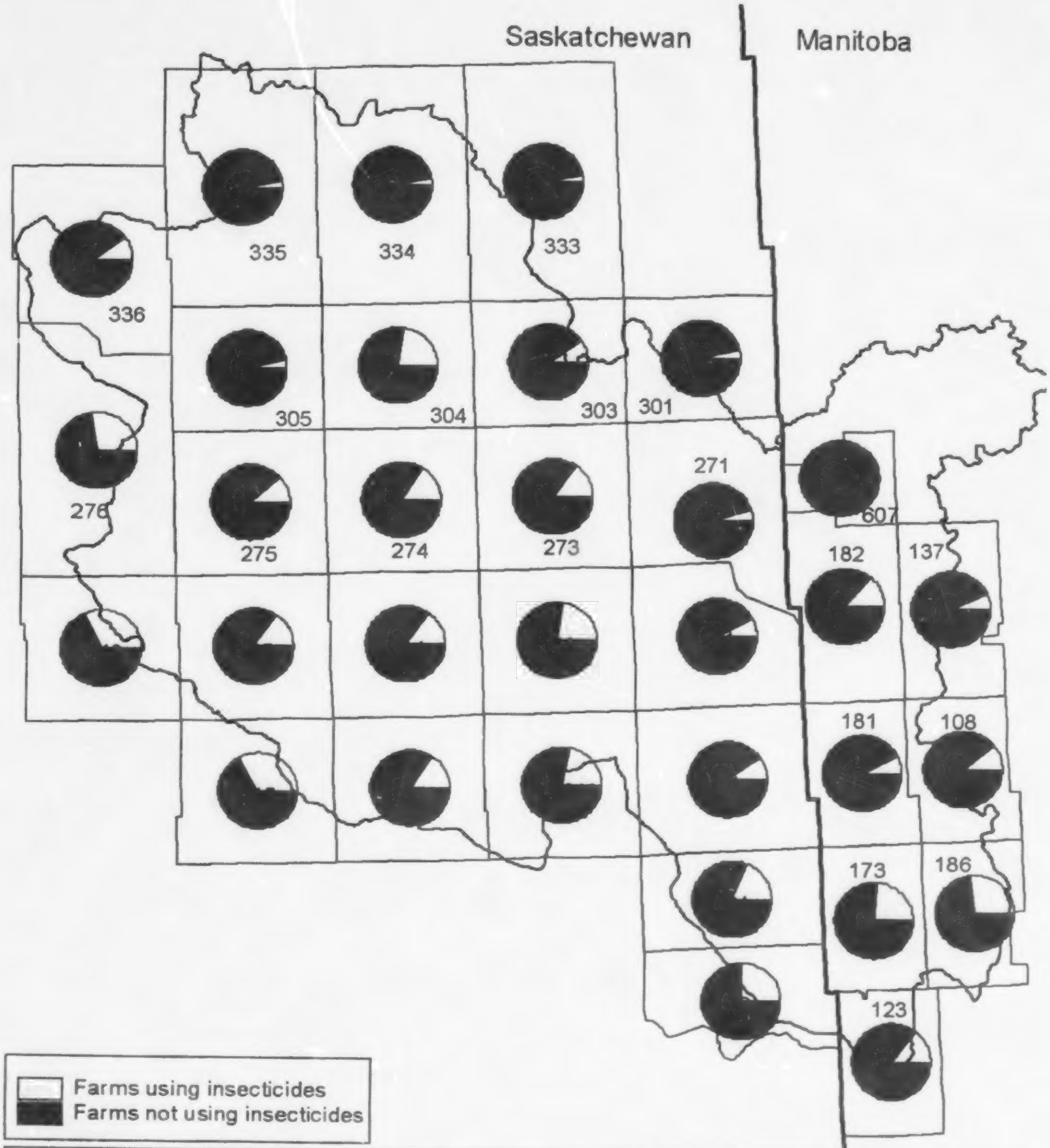
123
Farms using herbicides
Farms not using herbicides

Saskatchewan Agriculture and Food

5 0 5 10 15 20 25 Miles
N

Prepared by	Geomatics Unit, Statistics Branch [SL]
Data source	1996 Census of Agriculture, Statistics Canada (Table 8.1, 10)
Date	November 2, 1999

Figure 5.4
Insecticide Usage in the Upper Assiniboine River Basin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173
186
123
Farms using insecticides
Farms not using insecticides

Saskatchewan Agriculture and Food

5 0 5 10 15 20 25 Miles

N

Prepared by	Geomatics Unit, Statistics Branch [SL]
Data source	1986 Census of Agriculture, Statistics Canada (Table B.1, 10)
Date	November 2, 1999

(2) Herbicides

(a) contact herbicides - direct contact with plant tissue provides control
(b) systemic or translocated herbicides - control by being absorbed by the plant
(c) growth regulators - control by regulating growth characteristics of the plant
(d) selectivity - non-selective: kills or suppresses all vegetation; selective: kills or suppresses target vegetation
(e) time of application - pre-plant: soil applied or soil incorporated; pre-emergent: applied prior to crop emergence; post-emergent: applied after crop emergence

(3) Fungicides

(a) protectant fungicides - applied before infection occurs, coverage important
(b) systemic fungicides - absorbed by the plant for somewhat longer term protection

5.2.1.2 Pesticide Classification by Formulation

(1) solution (SN)
(2) emulsifiable
(3) concentrate (EC)
(4) wettable powder (WP)
(5) flowable (F)
(6) dry flowable (DF)
(7) granule (G)
(8) water dispensable granule (DG)
(9) water soluble powder (WSP)
(10) amine (A)
(11) ester (E)

5.2.1.3 Pesticide Classification by Chemical Composition (Guide to Crop Protection, 2000)

(1) Biological Pesticides - are living organisms (or their spores) used to control pests, e.g., *Bacillus thuringiensis* (Bt)
(2) Inorganic Compounds - do not contain carbon, e.g., copper sulphate (blue-stone), aluminum phosphide (Gastoxin, an insecticide used to control insects in stored grain)
(3) Organic Compounds - contain carbon, make up over 22 groups or families of chemicals. The major organic chemical groups are:

(a) Organochlorine compounds: most are insecticides with a high toxicity, e.g., lindane (Vitavax, DB Green L Dual Purpose, NM Dual Purpose, Agrox. Foundation, and Premiere Plus), endosulfan (Thiodan, Thionex, and Endosulfan). They are generally persistent in the soil and can accumulate in fatty tissues.
(b) Organophosphorous compounds: most are insecticides, with high toxicity to mammals. They act as cholinesterase depressants affecting the central nervous system, e.g., malathion (Malathion and Fyfanon), dimethoate (Cygon, Lagon, and Hopper Stopper), chlorpyrifos (Lorsban and Pyrinex).
(c) Carbamate and thiocarbamate compounds - occur as:
    - insecticides that are highly toxic, e.g., carbaryl (Sevin), methomyl (Lannate) and carbofuran (Furadan)

- herbicides that are low toxicity to mammals e.g., triallate (Avedex)
- fungicides that are very low toxicity e.g., maneb (DB Green L)

(d) Chlorophenoxy compounds: most are herbicides with low to very low toxicity to mammals and include 2,4-D, MCPA, and Mecoprop.

(e) Substituted ureas: most are herbicides with moderate toxicity e.g., linuron (Linuron 480, Afolan F, and Lorox Toss-N-Go)

(f) Triazines and triazoles: most are herbicides with moderate toxicity. They tend to persist in the soil e.g., atrazine (Atrazine), cyanazine (Bladex), metribuzine (Sencor), simazine (Simazine and Princep), and amitrole (Amitrol)

(g) Botanicals and pyrethroids: derived from plant materials and include pyrethrin, nicotine, and rotenone. Pyrethroids are synthetic compounds similar to pyrethrin, but modified to improve stability.

(h) Nitrophenolic compounds - have a strong staining, yellow colour and are highly toxic to humans and animals. They are insecticides, fungicides, and herbicides including crop desiccants.

(i) Dinitrotoluidine compounds: these are herbicides that are yellow in colour, and have a low toxicity to mammals e.g., trifluralin (Trifluralin).

(j) Phthalimides: these fungicides are moderately toxic to humans e.g., captan (Captan).

(k) Other chlorinated organic acids: this group has relatively low toxicity to humans, but residues may persist in the soil e.g., picloram (Tordon)

(l) Pyridyllium compounds: are herbicides capable of rapid dessication of foliage (e.g., diquat and paraquat). These chemicals are highly toxic to humans, especially if inhaled.

(m) Other: included alcohols, aldehydes, acetamides, pyridines, nitriles and more.

5.2.1.4 Toxicity of Pesticides

It is important to understand the relative toxicity of the pesticide in question. Toxicity varies with the type of formulation used, the route of absorption into the body, and body weight. Susceptibility of humans to pesticide poisoning also varies with age, sex, nutritional state, and health status. Relative toxicity is measured as the lethal dose 50 percent (LD50) value of the active ingredient of each pesticide (Saskatchewan Agriculture and Food and Saskatchewan Labour, 1998). The smaller the LD50 value, the more toxic the compound. Knowing the relative toxicity of a compound allows applicators the ability to choose less hazardous pesticides to control pests.

5.2.1.5 Pesticides Toxic to Fish

(1) Herbicides

(a) acrolein (Magnacide)
(b) copper sulphate
(c) bromoxynil (Pardner, Laser, Torch)
(d) metolachlor (Dual II)

(2) Insecticides
(a) azinphos-methyl (Guthion)
(b) bendiocarb (Ficam, Trumpet)
(c) fenthion (Spotton)
(d) carbofuran (Furadan - banned in 1996)
(e) malathion (Malathion)
(f) chlorpyrifos (Lorsban, Dursban)
(g) methamidophos (Monitor)
(h) cypermethrin (Ripcord, Cymbush, Stockaid)
(i) deltamethrin (Decis)
(j) parathion (Guardsman)
(k) dicofol (Kelthane)
(l) permethrin (Ambush, Ectiban)
(m) disulfoton (Di-syston)
(n) rotenone (Deritox)
(o) endosulfan (Endosulfan)
(p) terbufos (Counter)
(q) oxydemeton-methyl (Metasystox-R)

(3) Fungicides
(a) captafol (Captafol)
(b) maneb (DB-Green L, N-M Drill Box)
(c) dodemorph (Meltatox)
(d) pentachlorophenol (Wood Preserver)
(e) folpet (Phalaton, Folpan)

5.3 Pesticides Discussed in the Dillon Consulting Limited, Literature Review

Clarification for some of the pesticides discussed in the literature review conducted by Dillon Consulting Limited is warranted.

5.3.1 DDT

This insecticide was banned for agricultural use in Canada in 1970. Use of DDT after that date was subject to strict control and only allowed if no other option existed. In 1985 all remaining DDT uses were withdrawn from Canada under any circumstances. The USA banned DDT for all uses in 1973. DDT is still used extensively in some countries to control malaria.

5.3.2 2,4,5-T

Canadian registration for this herbicide was discontinued January 1, 1986. A member of the chemical group of chlorophenoxy compounds, these herbicides have a very low toxicity to humans.

5.3.3 Atrazine

This herbicide is registered for use on corn only. There is very limited cropping of corn in the Basin. The limited amount of corn that is grown in the Basin is usually harvested as silage. Common practice is to use no herbicides on the silage corn unless weed conditions get ahead of the corn crop in the spring. There may also be some limited use of atrazine on sweet corn grown for local use.

5.3.4 Endosulfan

Endosulfan includes Thiodan and Thionex. Endosulfan is registered for insect control on potato, sunflower, and bean crops. The acreage committed to these crops is very limited in the Basin.

5.3.5 Metolachlor

Metolachlor is the active ingredient in Dual II. The herbicide is registered for use on corn, soybeans, potatoes, dry beans, sweet white lupins, and processing peas. Based on the limited acres of these crops in the Basin, use of metolachlor is negligible.

5.3.6 Phorate

Phorate is the active ingredient in Thimet. The insecticide is registered for use on potatoes. Based on the limited acres of potatoes grown in the Basin, use of phorate is negligible.

5.4 Water Sources for Pesticide Application

Virtually all pesticides must be mixed with water for application. There are two primary reasons why a clean water supply is important for effective pesticide control:

1) clean water enables the pesticide to perform as expected; and
2) clean water reduces the frequency of plugged nozzles.

Extreme caution is imperative when filling the sprayer to ensure that no pesticide is allowed to enter the water supply. Many community wells forbid filling a sprayer directly from the well. Only nurse tanks can be used. This is also a very good practice to follow for private wells.

When pumping directly from wells and surface water, the end of the delivery hose should never be extend into the tank and the pumping system should be equipped with an anti-siphoning device. The sprayer tank should not be allowed to overflow during filling and chemicals should not be handled in the vicinity of the water supply in case of accidental spills.

Improperly sealed abandoned wells in the spray path of pesticides or in the vicinity of handling the chemicals can offer an immediate pathway for the pesticides to reach groundwater. All abandoned wells should be decommissioned properly. Existing wells should have the cribbing/ground surface area sealed and contoured properly. Surface water supplies should be afforded sufficient protection from accidental spills.

5.5 Legislation

Pesticide use is regulated in both Saskatchewan and Manitoba.

5.5.1 Federal

Federal control over pesticides is through the *Pest Control Products (Canada) Act*. The Act deals primarily with the registration of pesticides but it does have a section which deals directly with pesticide application. It states that pesticides must be applied in accordance with label directions. This means that a pesticide can only be used for the purpose for which it was created.

5.5.2 Saskatchewan

The Pest Control Products (Saskatchewan) Act regulates the use, handling and distribution of pesticides in Saskatchewan. It requires that all commercial or custom pesticide applicators be trained and licensed. Pesticide applicator training is offered by the Saskatchewan Institute of Applied Science and Technology (SIAST) either as classroom or home study courses. Upon successful completion, a pesticide applicator licence can be applied for annually. Pesticide recertification/training is required every five years. Some of the Saskatchewan pesticide regulations are:

1) Any person who applies pesticides for other than their own use must have a valid pesticide applicators licence.
2) Any person who conducts a business of applying pesticides must have a valid pesticide service licence.
3) Any person who sells pesticides must have a valid pesticide vendor licence.
4) All licensed applicators must keep a record of every pesticide application and keep these records for three years.
5) All licensed aerial applicators must have $25,000 drift insurance.
6) No person shall apply pesticides to open bodies of water without a permit.
7) No person shall use pesticides in a manner other than what is described on the pesticide label.

Regulations regarding distance restrictions, wind speed restrictions, application method (air vs. ground), etc., vary from product to product. These specific restrictions are outlined on the pesticide label for each individual product. The label is considered a legal document and the application methods listed on the label must be followed. This applies to all pesticide applicators.

Some examples of these restrictions are: do not apply this product within 15 m of an environmentally sensitive area; do not apply when bees are actively foraging; and you must be a certified applicator to apply this product.

5.5.3 Manitoba

The purpose of *The Manitoba Pesticides and Fertilizers Control Act* (PFCA) is to ensure safe pesticide use by making pesticide dealers and applicators more knowledgeable about pesticide use and safety. The PFCA outlines training, examination and licensing requirements to meet this goal. Under the PFCA, all commercial pesticide applicators and retail pesticide dealers are required to have a license.

Pesticide dealer/applicator training material and examinations are available from Assiniboine Community College, 1430 Victoria Avenue E., Brandon MB, R7A 2A9. Courses are offered in specific licensing categories depending on the type of pesticide application being done or type of pesticides being sold. Course re-certification is required every five years.

A dealer/applicator can apply for a license once training is complete. Pesticide licenses are issued by Manitoba Agriculture and Food, 201-545 University Crescent, Winnipeg MB, R3T 5S6. Licenses are renewable yearly for a fee of $50.00. Commercial applicators must provide evidence of liability insurance as a licensing requirement.

The PFCA requires a minimum of $250,000 general liability and $25,000 spray drift or chemical misuse coverage. The PFCA requires pesticide dealers to keep a record of all commercial and restricted pesticides sold and requires a record of pesticide application be kept by all pesticide applicators.

Exemptions under the PFCA include:

1) Fertilizers, domestic label pesticides, wood preservatives, antimicrobials, animal repellants, feed preservatives, bactericides;
2) Farmers who apply pesticides to their own land and for not more than 3 individuals per year on less that 500 ha off their own farm in any year; and
3) Wholesale pesticide vendors or distributors.

The Pesticide Advisory Committee advises the Manitoba Agriculture and Food Minister on issues relating to the PFCA. The committee consists of seven members representing the Manitoba and municipal governments, dealers/applicators and producer groups. Penalties under the PFCA include fines ($100 to $1000), and imprisonment (60 days to six months) or both.

5.6 Agricultural Chemical Container Disposal

5.6.1 Saskatchewan

In Saskatchewan, there are two programs presently in place that deal with the collection of empty agricultural chemical containers. Many pesticide collection sites are operated by local rural municipalities. Some of these sites have been closed and new sites established that are operated by suppliers of the pesticides. Prior to returning empty agricultural chemical containers farmers are required to clean, triple rinse, and properly drain the containers. The empty containers are collected from the sites by the end of each crop year.

The first program began in 1982, and was referred to as the "Pesticide Container Management Program." Saskatchewan Environment and Resource Management (SERM) provided funding for initial start-up of the sites, developed extensive siting criteria, and conducted site inspections. However, the day-to-day operations and maintenance of the program was the responsibility of the local municipality (Appendix IV).

The second program, "Voluntary Container Collection Program," began operation at the start of the 1999 crop season. It is co-ordinated by the Saskatchewan Pesticide Container Management Association Inc. in conjunction with the Crop Protection Institute. Crop protection distribution companies and their participating retail dealers are voluntary participants in the program. Once collected, the empty, clean containers are transported to a central location for shredding. The shredded plastic is shipped to recycling plants for the manufacture of products such as curb stops and fence posts.

These two programs do not deal with unwanted and unused chemical product. Within Saskatchewan, *The Pest Control Products (Saskatchewan) Act* regulates the improper use, storage, disposal, or abandonment of agricultural chemicals and containers. Local environment offices should be notified if chemicals/chemical containers are improperly used or discarded.

5.6.2 Manitoba

In Manitoba, the pesticide container collection sites are regulated under *The Dangerous Goods Handling and Transportation Act* which ensures each site is permitted. The permit ensures that surface and groundwater are protected and that each site is lined, bermed and suitable for receiving the containers. Sites were originally established and maintained within Manitoba municipalities and weed districts with monies supplied by the Association for Clean Rural Environment (ACRE). ACRE received funding from the Crop Protection Institute (CPI) from a levy associated with the sale of pesticide product. Since 1995, the CPI has reduced direct funding to ACRE and instead has funded a private contractor with a mobile operation to shred/crush and dispose of containers at each site. Available funds from ACRE to pay the municipalities for their continued participation in the collection program have been used up. One of the proposed solutions under consideration is to have depots established at retail outlets instead of the current sites. The municipalities have asked Manitoba Conservation to regulate and impose a pesticide container sales levy under *The Wrap Act* to fund the on-going program. Manitoba is currently reviewing the program to ensure that the problems are resolved and that the handling and disposal of pesticide containers continues to operate in an efficient manner.

5.6.3 Agricultural Chemical Container Collection Depots

Table 5.1 (Saskatchewan only) and Figure 5.5 (map) identify the agricultural chemical container collection depots in the Basin. Excluded from the table, are the container collection sites established through dealer participation within the Upper Assiniboine River Basin (Saskatchewan only). These dealer sites were only established over the last two years and include the following locations: Kamsack (Pioneer Grain Co.), Rama (Rama Co-op Association Ltd.), Rhein (Imperial Oil), Yorkton (Cropmate - UAP, Imperial Oil, Parrish and Heinbecker Ltd.). The municipal sites are being gradually closed in preference to the dealer sites.

5.6.4 Agricultural Pesticide Collection Sites

In early spring 1999, the "Saskatchewan Pesticide Return Program" was initiated for the collection and disposal of unwanted, and obsolete agricultural pesticides. In 1999, only the southern part of the Province participated. In 2000, central Saskatchewan is being targeted and Basin residents south of Hwy No. 16 can participate. In 2001, the program will cover areas north of Hwy No. 16. The program focuses on the collection of pesticides only. Products such as antifreeze, solvents, paints, and other hazardous wastes will not be accepted. Although, a similar program does not exist in Manitoba, negotiations are currently underway to get a similar program organized (personal communication, Cam Davreux, Crop Protection Institute 416-622-9771).

5.7 Tillage and Seeding Activity

Approximately 13 percent of soils within the Basin are coarse textured (sands and sandy loams) and are located around Good Spirit Lake, Sturgis, and Spy Hill. Permanent cover should be the appropriate land use for these soils with the associated forage and livestock production. Over 83 percent of the Basin soils are a moderate texture (loams and clay loams). Combined with normally abundant precipitation, these high quality, fertile soils are conducive to intensive crop production.

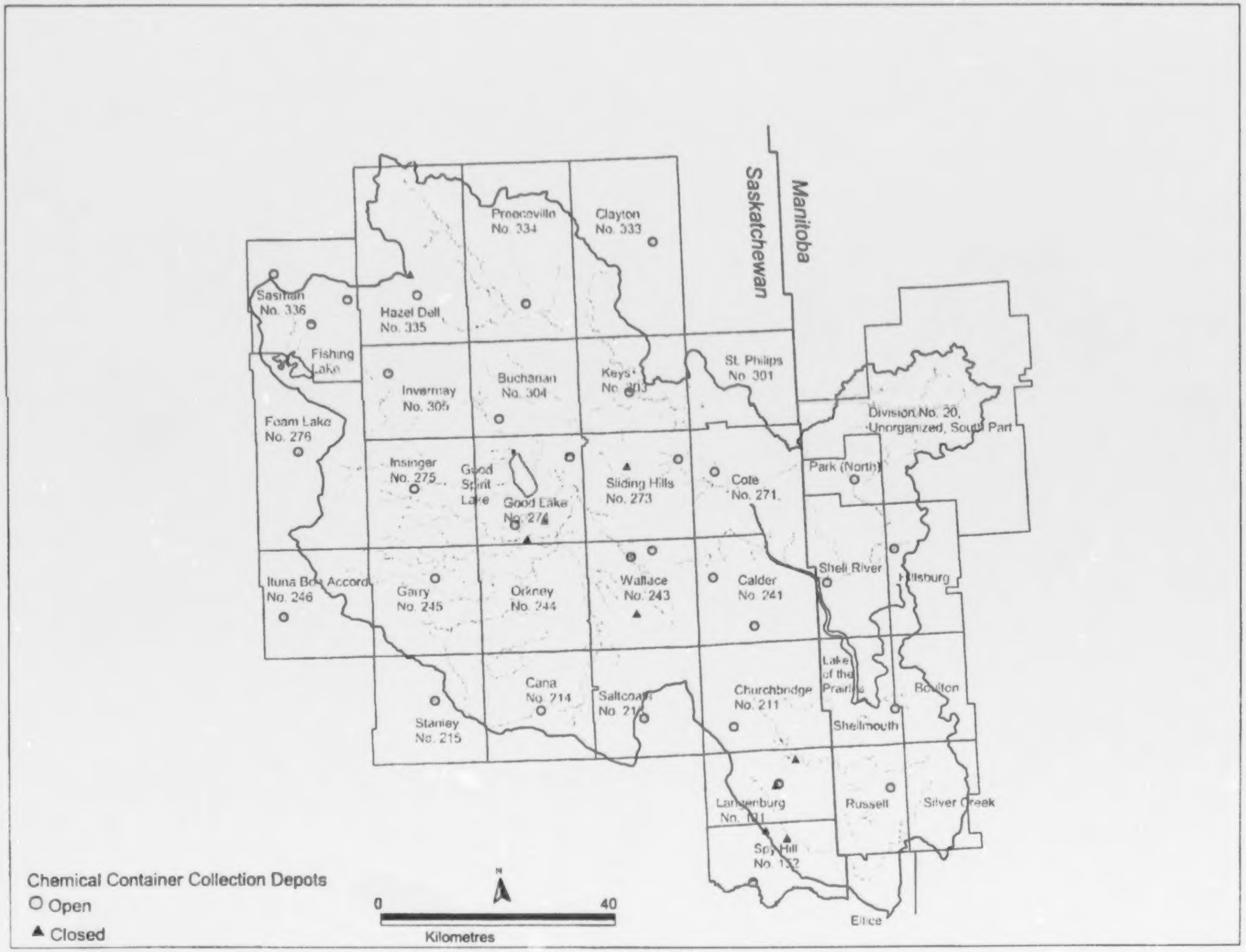
There are countless definitions used to report on types of tillage, seeding, and cropping systems. Although usually understood by everyone involved with the industry, the terms defining the various seeding systems tend to have different implications and need to be defined for clearer understanding. Generally, all tillage, seeding, and cropping practices fall into two broad categories: conventional tillage and conservation tillage.

When conservation systems are chosen, emphasis on the importance of field machinery shifts from tillage units to the seeding and harvesting equipment. Managing increased amounts of crop residue becomes more of a challenge in putting the seed in the ground. High amounts of residue on the soil surface can increase plugging and hair pinning during seeding. Ensuring effective spread of crop residues at harvest can be a challenge. Seeding directly into standing stubble (direct seeding) is the ultimate goal of conservation systems.

Table 5.1
Municipal Agricultural Chemical Container Collection Depots in Saskatchewan

Rural Municipality	**Land Location (portion, Section, Township, Range, Meridian)**
Spy Hill, No. 152	SW 16-18-32 W1
Spy Hill, No. 152 - **discontinued site**	**NW 30-19-31 W1**
Spy Hill, No. 152 - **discontinued site**	**SE 22-19-31 W1**
Langenburg, No. 181	SE 04-21-31 W1
Langenburg, No. 181 - **discontinued site**	**SW 04-21-31 W1**
Langenburg, No. 181 - **discontinued site**	**SE 25-21-31 W1**
Fertile Belt, No.183	SW 35-19-01 W2
Churchbridge, No. 211	SE 29-22-32 W1
Saltcoats, No. 213	SW 04-23-02 W2
Cana, No. 214	SW 15-23-05 W2
Stanley, No. 215	SE 27-23-08 W2
Calder, No. 241	NW 17-25-31 W1
Calder, No. 241	SE 31-26-32 W1
Wallace, No. 243	SW 20-27-02 W2
Wallace, No. 243 - **discontinued site**	**NE 32-25-02 W2**
Orkney, No. 244	SE 26-27-02 W2
Garry, No. 245	NE 02-27-08 W2
Ituna Bon Accord, No. 246	NW 03-26-12 W2
Cote, No. 271	NW 27-29-32 W1
Sliding Hills, No. 273	SE 10-30-01 W2
Sliding Hills, No. 273 - **discontinued site**	**SW 05-30-02 W2**
Good Lake, No. 274	SW 19-28-05 W2
Good Lake, No. 274 - **discontinued site**	**NW 24-28-05 W2**
Good Lake, No. 274	SE 15-30-04 W2
Good Lake, No. 274 - **discontinued site**	**NW 04-28-05 W2**
Insinger, No. 275	NE 20-29-08 W2
Foam Lake, No. 276	SE 30-30-11 W2
Keys, No. 303	NW 16-32-02 W2
Buchanan, No. 304	SW 35-31-06 W2
Invermay, No. 305	SW 11-33-09 W2
Clayton, No. 333	NW 20-36-01 W2
Preeceville, No. 334	SE 03-35-05 W2
Hazel Dell, No. 335	SE 15-35-08 W2
Hazel Dell, No. 335 - **discontinued site**	**NE 33-35-08 W2**
Sasman, No. 336	NW 11-35-10 W2
Sasman, No. 336	NE 22-34-11 W2
Sasman, No. 336	SW 02-36-12 W2

Figure 5.5
Location of Municipal Agricultural Collection Depots in the Basin


Manitoba
Saskatchewan
Preeceville No. 334
Clayton No. 333
Sasman No. 336
Hazel Dell No. 335
Fishing Lake
Invermay No. 305
Buchanan No. 304
Keys No. 303
St. Philips No. 301
Division No. 20, Unorganized, South Part
Foam Lake No. 276
Insinger No. 275
Good Spirit Lake
Good Lake No. 274
Sliding Hills No. 273
Cote No. 271
Park (North)
Ituna Bon Accord No. 246
Garry No. 245
Orkney No. 244
Wallace No. 243
Calder No. 241
Shell River
Hillsburg
Lake of the Prairies
Boulton
Stanley No. 215
Cana No. 214
Saltcoats No. 213
Churchbridge No. 211
Shellmouth
Langenburg No. 181
Russell
Silver Creek
Spy Hill No. 152
Ellice
Chemical Container Collection Depots
○ Open
▲ Closed
0
40
Kilometres
N

The Saskatchewan Soil Conservation Association focuses on direct seeding systems (seeding into standing stubble) and measures the level of soil disturbance associated with the seeding operation as low disturbance or high disturbance. The amount of disturbance is a factor of opener type (knife, disc and coulter, spoon or sweep), row spacing, and speed.

The Prairie Farm Rehabilitation Administration (PFRA) has conducted an annual survey of crop residue and seeding systems on over 500 sites in east-central Saskatchewan since 1997. Fields at the corners of townships (Sections 1, 6, 31, and 36) are monitored annually and parameters such as the type of crop grown, amount of stubble, orientation of the stubble (standing, flat, or mixed), most recent field operation, type of packing system, row spacing, seed spread (type of opener), and type of seeding system (conventional, minimum till, or zero till) are measured. The goal of the survey is to determine the percentage of cultivated lands at risk to soil erosion and, for the long-term, to gather and analyze sufficient data to be able to establish trends in seeding and cropping systems. Three years of data reveal that conventional tillage systems are practiced on 85 percent of the annually cropped lands in east-central Saskatchewan. The remaining 15 percent of lands involve some type of conservation tillage (13 percent are minimum tillage and 2 percent are zero tillage).

Susceptibility to erosion is dependent upon soil type, soil texture, slope, field implements, climate and crop rotations (high residue crops vs. low residue crops). On all but steeply sloping fields, an estimated 1.12 tonnes of residue per hectare (1000 lbs/acres; 50 percent cover) is adequate to fully protect the soil from erosion. The survey revealed that, of the 85 percent of lands under conventional tillage in east central Saskatchewan, 94 percent of the fields had insufficient amounts of crop residue present to protect from the threat of erosion. Comparatively, 50 percent of minimum tillage fields and 28 percent of zero tillage fields had insufficient crop residue cover to protect the soil from erosion risk.

Prairie Farm Rehabilitation Administration is currently conducting an analysis called the "Prairie Agricultural Landscapes" (PAL) project in which land use (as determined by Ag Census data) is being correlated to soil landscapes of Canada. Land use categories are broadly defined as being high pasture, medium pasture and low pasture. Low pasture is split into three additional categories of low, medium and high summer fallow. Agricultural Census data from 1996 provide information on average size of farm, number of cattle per farm, percentage of summer fallow, and percentages of crops grown.

According to PAL, the vast majority of farms within the Basin fall into a category defined as low pasture and medium summer fallow. Approximately 28 percent of land is in pasture and hay, with an average of 52 cattle per farm. The annually cropped area is 62 percent cereal, 19 percent summer fallow, 10 percent oilseed, 4.5 percent pulse, and 2 percent flax.

This compares roughly to the 1996 Canadian Wheat Board data for east central Saskatchewan which shows, on average, that 25 percent of land is pasture or tame hay. Of the annually cropped area, 46 percent is cereal, 24 percent is summer fallow, 20 percent is oilseed, 5 percent is flax, and 4 percent is pulse.

5.8 Fertilizer

Soil fertility is an important factor in annual crop and forage production. Plants require at least 16 different nutrients for growth. The major (macro) nutrients required for optimal field crop production on the Prairies are nitrogen (N), phosphorous (P), potassium (K), and sulphur (S). The fertilizer form of P is phosphate (P_2O_5) and of K is potash (K_2O)). In addition to nutrient levels, soil pH and electrical conductivity (indication of salinity) are key characteristics that influence soil fertility.

Agricultural producers enhance soil fertility by augmenting soil nutrient levels with either commercial fertilizer blends (inorganic fertilizer), manure (organic fertilizer), or a combination of both. It has been long established that farmers should annually soil test individual fields to compare plant-available nutrient levels of the soil to fertilizer requirements for the anticipated yield and nutrient uptake of the selected crop. Crop uptake of nutrients varies not only with yield, but is also affected by soil and climatic conditions. Nutrient balancing (i.e., matching the estimated nutrient uptake of the crop with the nutrient availability of the particular soil in each field) is the underlying premise for all fertilizer applications in order to economically achieve optimal yields and prevent nutrient surpluses.

Nitrogen content of a soil varies with soil zone, soil moisture, soil texture, and soil organic matter content. Nitrogen is critical for plant growth, yield, and protein content of the seed. Phosphorous is important for rooting, flowering and seed production. Potassium is necessary for photosynthesis, osmotic regulation and activation of enzyme systems. Sulphur is important in S-sensitive crops such as canola. Nitrogen and sulphur are both very mobile in the soil and as a result, soil sampling depths to 60 cm are recommended. Most phosphorous is readily adsorbed (or fixed) to soil particles and generally is not mobile. However, phosphorous can be transported in surface run-off by either being attached to soil particles suspended in run-off (i.e., P attached to suspended solids or sediment) or, to a lesser extent, a fraction of soil phosphorous can become dissolved in soil solution.

Good business planning dictates that in order to maximize profits agricultural producers must be careful to keep input costs down and not over fertilize. Nutrient balancing is essential in managing the amount of nutrients produced and utilized on the farm. Over application of any fertilizer, either manure or commercial fertilizer, can be detrimental and is not recommended. Over application of nitrogen can soon become evident in the crop through lodging, delayed crop maturity, elevated nitrate levels in forages and unrealized profit. Over application of phosphorous can potentially occur in lands where excessive amounts of fertilizer (inorganic or organic) have been applied, and also where fertilizer application rates have focused on balancing for nitrogen only. As N and P are major plant nutrients, N and P loading of surface water sources can lead to increased eutrophication and excessive algae growth.

In addition to nutrient balancing, vegetative buffers and filter strips are highly effective at trapping and filtering nutrients and sediments in run-off from arable lands. Depending upon steepness of slope and soil texture, vegetative buffers established adjacent to riparian areas should be a minimum 30 m wide and are recognized as a best management practice on all agricultural lands draining into surface water bodies.

The threat of non-point source pollution to surface water and groundwater quality by agricultural fertilizers within the Basin is considered minimal. Increased awareness of nutrient management, prevention of nutrient loading, and possible adoption of farm mineral accounting systems will lead to preventing surplus nutrient levels and reduce the risk of water quality problems in the future.

Best management practices (BMPs) have been developed for the application of manure as a fertilizer. It is advisable that BMPs be developed for commercial fertilizers as well and, further to that, annual cropping practices in general.

5.9 Summary and Recommendations

Based on the observations in the literature review by Dillon Consulting Limited, "Upper Assiniboine River Basin Water Quality Study - Final Report, November 1998" and general knowledge of the Basin, there are several key points that should be targeted by and for the agricultural industry with respect to improving water quality.

1) Proper decommissioning of abandoned wells and maintenance of existing wells.

2) Continued use of pesticide container disposal sites along with proper on-farm preparation of the containers for disposal - triple rinsing, punctured containers.

3) Without extensive testing, the effect from hazardous substances and storage sites (i.e., chemical collection depots, landfills, discontinued bulk fuel depots, and gas stations) and the full extent of potential contamination is difficult to determine.

4) Construction of new storage facilities must comply with more stringent regulations that protect the environment from spills and leaching of hazardous substances.

5) Education to caution the pesticide user to avoid cleaning sprayers and chemical containers near open water.

6) Education to inform the pesticide user about applying product at the proper rates and to adhere to label restrictions and recommended practices.

7) Joint effort among all agencies to develop a 'Glossary of Terms' that are representative and consistent within the agricultural industry for seeding/tillage/rotation systems.

8) Best management practices should be developed for annual cropping practices.

6 Municipal Lagoons and Water Quality

6.1 Introduction

Throughout the various watershed drainage regions that make up the Upper Assiniboine River Basin there are 32 towns that operate licensed multi-celled lagoons as part of their wastewater treatment system (Dillon Consulting Limited, 1998). These systems utilize the forces of nature to treat the effluent and are designed to provide the minimal amount of treatment required by both the provinces of Saskatchewan and Manitoba for towns and small villages. The various licenses for these systems allow for the discharge of the lagoons once or twice yearly into the local watercourse. While many of the towns do not discharge their treated effluent directly into the Assiniboine River, all drainage from this area eventually drains into the river. The Town of Roblin is the only community utilizing lagoons within the Basin that provides alternate disposal methods for their treated effluent. The City of Yorkton has a more advanced mechanical wastewater treatment system, which treats the effluent on a continuous basis allowing for continuous discharge to the river (Dillon Consulting Limited, 1998).

Each province has discharge objectives and regulations that control the construction, operation, and pollution control mechanisms for lagoons. Operating licence/permits for each individual project are designed to protect the receiving water bodies from contamination or pollution. While the requirements of each licence/permit varies, each requirement is specific to the local situation and takes into account the mixing zone of the receiving body of water, flows present, and the time of year.

Since there are a number of sewage treatment facilities within this drainage area, river water quality could be a major concern to the Basin and downstream water bodies due to accumulation of nutrients such as nitrogen and phosphorous. It is these nutrients that accumulate in the water bodies and act as fertilizers and encourage algal growth. The accumulation of nutrients in the various water bodies is of concern as it can lead to a decrease in water quality and eutrophication of the lakes over the long-term.

Sludge and liquid effluent from municipal and agricultural waste contain trace metals. Land applications can redistribute these in the aquatic environment where they can be transferred through the food chain. Some are highly mobile and can leach into groundwater or runoff (EPA, 1976). Others accumulate in surface soils where runoff can transfer trace metals to surface water bodies via eroded soils (USCATST, 1992; EPA, 1976).

6.1.1 Municipal Wastewater

Municipal wastewater comes from our homes, businesses, and industries. It carries the wastes of daily living, such as water from showers, toilets, laundry, dishwashers, and business operations. Municipal wastewater is usually gray in colour and most often has a musty odour. Wastewater is approximately 99.9 percent water, with the remaining 0.1 percent being solids. Almost half (40 percent) of these solids are dissolved solids - they are dissolved in the wastewater much like salt is dissolved in sea water. The rest of the solids are suspended solids.

Lagoons are shallow ponds that utilize components of nature such as sunlight, algae, microorganisms, and oxygen to interact and treat or stabilize the wastewater. They are designed to provide secondary treatment, the minimal amount of treatment required by both the provinces of Saskatchewan and Manitoba for towns and small villages. Although lagoon construction can cost in excess of $100,000 they are relatively inexpensive compared to more advanced systems, have minimal operating costs, and are simpler to operate.

6.1.2 Wastewater Treatment/Lagoons

Within the Upper Assiniboine River Basin, two processes for wastewater treatment are found, utilizing a system of at least two ponds or cells, referred to as lagoons. Many larger lagoon systems may contain several treatment and storage cells. When wastewater is treated properly, many suspended and dissolved pollutants are removed and the effluent can be released safely to the environment. There are three types of lagoon treatment cells used in Saskatchewan: facultative lagoons, aerated lagoons, and anaerobic lagoons.

1) Facultative Lagoons have an aerobic (containing oxygen) surface layer and an anaerobic (without oxygen) bottom layer. Facultative lagoons are the most common type with approximately 500 in Saskatchewan. All the lagoons located within the Saskatchewan portion of the Basin are a faculative treatment cell design.

2) Aerated Lagoons add oxygen artificially to the wastewater with various types of aeration devices, and they can treat wastewater in a smaller treatment cell. However, they do require a power input. Aerated lagoons tend to be smaller and deeper than facultative lagoons.

3) Anaerobic Lagoons operate without any dissolved oxygen. Wastewater treatment is provided by anaerobic microorganisms that can thrive without dissolved oxygen. These lagoons are smaller but deeper than the facultative type.

6.1.3 Treatment

1) Primary Treatment involves the physical removal of the solid materials in the wastewater that readily settle out by gravity, and takes place in the first cell, called the treatment or primary cell.

2) Secondary Treatment - purifies wastewater by removing organic materials through biological processes, and takes place in the secondary cell. It is also referred to as the storage cell because it stores the wastewater between releases into the environment. Processes within the secondary cell utilize microorganisms (bacteria and other small organisms) to consume organics such as fats, carbohydrates, and proteins that are

dissolved in the wastewater. Aerobic microorganisms use oxygen and give off carbon dioxide as they consume the organic "food" during secondary treatment. Anaerobic microorganisms also use this food source, but they do not use oxygen, and they give off gases such as methane and hydrogen sulphide.

6.2 Legislation

6.2.1 Saskatchewan

Within Saskatchewan, lagoon construction and operation are subject to The Water Pollution Control and Water Works Regulations (WPC and WWRs) of *The Environmental Management and Protection Act* (EMPA), as well as *The Water Corporation Act* (WCA). The highlights of the legislation include:

- Construction or alteration of a lagoon requires approval by Sask Water (WCA).
- A permit is required for wastewater disposal from Saskatchewan Environment and Resource Management (EMPA).
- Treated wastewater must meet requirements set by the Minister of Environment and Resource Management (EMPA).
- A minimum of secondary wastewater treatment or use of facultative lagoons is required in Saskatchewan (WPC and WWRs).
- Facultative lagoons must have a minimum of two cells operating in series - one after the other (WPC and WWRs).
- A minimum size for primary cells is specified (WPC and WWRs).
- Lagoons cannot be discharged between November 1 and spring runoff (WPC and WWRs).
- Tests must be done and records maintained as required by the Minister of Environment and Resource Management (WPC and WWRs).

Sask Water approves wastewater treatment facility construction applications and issues a permit to operate. Applications are then sent to Saskatchewan Environment and Resource Management for approval of health and environmental elements, and to issue a permit for the sewage works. This permit sets out the required testing and record keeping, and identifies any limits that the treatment facility may be required to meet.

Private wastewater treatment and disposal, which occurs where there is no municipal collection system, is subject to regulations and permitting administered by Saskatchewan Health. In the case of small commercial developments, (i.e., small motels, trailer courts and small restaurants, etc.), where the wastewater flow rate is less than 18 cubic metres (4,000 gallons) per day, the construction of wastewater treatment and disposal facilities requires approval from Sask Water, and is subject to regulations and permitting administered by Saskatchewan Health.

During an emergency situation a permit may be amended to reflect actual operating circumstances. For example, recent years of excessive rainfall have resulted in emergency discharge of effluent from some systems which incorporate evaporation cells. In such an event, samples are taken prior to discharge and have shown to be suitable for release to the environment because the effluent primarily consists of rainwater. There are also some communities, although allowed to discharge twice a year, that do not discharge at all. This may be due to decreasing population, minimal snow and rain moisture or drought like conditions causing excessive evaporation.

6.2.2 Manitoba

All lagoon operations and discharges fall under *The Manitoba Environment Act* and must be licenced to operate. A license is issued once an environmental impact assessment and mitigation plan has been completed by the proponent. Specifications for discharge limits, lagoon construction details, operation and design loadings are normally a part of the license. Each license may be similar or unique depending upon the environmental conditions associated with its location.

Lagoon operations also fall under the Water Works, Sewage and Sewerage Disposal Regulation of *The Public Health Act*. One primary focus of this Act is to evaluate the additional hydraulic and organic loading from the new sub division proposal and expansions on the acceptable capacity sewerage works to receive it.

6.3 Factors Affecting Wastewater Treatment in Lagoons

Many natural factors affect how well lagoons work in treating wastewater. Ideal conditions for lagoon treatment occur during the long, warm, sunny days of summer, when a moderate breeze is blowing.

1) Wind Action - wind mixes the wastewater and adds the oxygen necessary for aerobic microorganisms to do their work.

2) Temperature - affects how much oxygen the wastewater can hold and determines how quickly the microorganisms will act to break down the organic materials in the wastewater. Treatment occurs most quickly when temperatures are high.

3) Sunlight - causes algae to grow in the lagoon. Algae, like other plants, give off oxygen as they grow. Aerobic microorganisms use this oxygen as they break down dissolved materials in the wastewater. These processes also help to destroy disease-causing bacteria.

4) Winter - treatment also occurs during the winter months when solids settle out in the treatment cell and anaerobic bacteria break down organic pollutants. Due to colder

temperatures and lack of natural aeration and sunlight, winter treatment is not as effective as treatment during the other seasons.

5) Unwanted Waste - although lagoon treatment systems can cope with most normal waste products, consumers are discouraged from disposing of wastes such as battery acid, solvents, paints, waste oil products, and other toxic or hazardous wastes into their municipal sewer systems.

6.4 Facility Operation, Maintenance, and Monitoring

6.4.1 Release of Wastewater

Adequately sized and properly operated lagoon systems provide treatment that meets provincial objectives. Treated wastewater from the lagoon storage cells may be released according to their licence specifications but generally occurs twice a year. The first release typically occurs during the spring runoff, the second during the fall - usually in late October. Within the Upper Assiniboine River Basin, 17 communities discharge treated wastewater directly into watercourses such as the Assiniboine River; nine communities discharge treated wastewater into localized water bodies, such as sloughs or small lakes; three communities utilize alternative disposal methods, such as effluent irrigation; and, three communities do not discharge wastewater as there is enough evaporation during the summer (see section 6.7).

During the spring release, wastewater treated in the lagoon and stored over the winter is discharged and mixes with the runoff from melting snow. In the fall release, wastewater treated and stored over the summer is discharged from the lagoon. After each release, the discharge valve from the storage cell is closed, and a valve between the treatment storage cells is opened briefly to "equalize" the cells. This prevents drying out of the cells after the spring release and freezing of the piping after the fall release.

Lagoons may be discharged into dry or flowing creek beds, rivers, sloughs, ditches, fields, pastures, and sometimes lakes. Communities must have agreements with landowners to allow for disposal of treated wastewater to private land.

6.4.1.1 Wastewater as a Resource

Saskatchewan Environment and Resource Management encourages the use of treated wastewater as a resource. For example, it can be used for irrigating crop land, a process known as effluent irrigation. Treated wastewater is often suitable for use in wetlands projects for rearing waterfowl.

6.4.1.2 Solids

The solid material that settles to the bottom of the lagoon is called sludge or bio-solids. Most of the bio-solids are decomposed by microorganisms in the lagoon. It is seldom necessary to remove the few bio-solids that remain. When removal does become necessary, these solids may be spread on nearby farmland, where they serve as a source of nutrients for crop growth. Communities should contact their local environment department representatives for guidelines prior to bio-solid disposal.

6.4.1.3 Odour

Odour is not normally a significant problem around lagoons. However, lagoons that are too small to serve a community's population sometimes have odour problems. Also, for a short period of time in the spring immediately after the ice melts, it is normal for lagoon systems to experience temporary odorous conditions. Gases such as hydrogen sulphide given off by anaerobic bacteria as they treat the wastewater under the ice will cause odours in the spring.

6.4.2 Permits/Licenses

6.4.2.1 Saskatchewan

In Saskatchewan, each community's wastewater treatment system is issued a permit that outlines how many samples must be collected by the community, where the samples must be taken from, how the samples must be analyzed, and which operating records must be kept.

Usually three samples are required. The first sample is taken upstream from the point of discharge, the second sample at the point of discharge, and the third sample is taken downstream from the point of discharge. The second and third samples are taken halfway through the discharge process. Samples are analyzed for the following parameters: total kjeldahl nitrogen; nitrate nitrogen; total phosphorous; total suspended solids; volatile suspended solids; dissolved organic carbon; 5-day 20° Celsius biochemical oxygen demand; total coliform bacteria; fecal coliform bacteria; conductivity at 25° Celsius; pH; alkalinity; calcium; magnesium; potassium; sodium; bicarbonate; carbonate; chloride; and sulphate.

Communities take samples to find out how well the lagoon treatment system is working and what effects the discharges are having on water quality in the receiving environment. The data obtained from sampling are primarily used as an indication of how well a system is working. Operating records would include dates of effluent discharges and the quantity of effluent discharged. Table 6.1 lists expected effluent quality produced by well operated treatment facilities that treat typical municipal sanitary sewage.

Table 6.1
Sewage Treatment Processes - Typical Effluent Quality

Process	BOD_5 mg/L	TSS mg/L	Total-P mg/L	Total-N mg/L	Total Coliforms /100 mL
Primary:					
- incl. anaerobic lagoons	75-150	50-110	5-7	25-45	$>2x10^{6}$
- with phosphorous removal	45-85	25-50	1-2	20-40	$>2x10^{5}$
Secondary:					
- biological (Mech.)	10-25	10-25	3.5-6.5	15-35	$2x10^{4}-2x10^{5}$
- aerated Lagoons	15-30	20-35	4-7	20-40	$2x10^{3}-2x10^{5}$
- aerobic Lagoons					
Spring	25-70	20-60	3.5-7	20-35	$<2x10^{3}-2x10^{5}$
Late Fall	10-30	10-40	2-5	5-20	$2x10^{2}-2x10^{4}$
Advanced:					
- secondary with chemical treatment (phosphorous control)	36660	36828	0.5-1.5	15-35	$2x10^{2}-2x10^{4}$

* levels required by SERM for communities within the Saskatchewan portion of the Basin.

6.4.2.2 Manitoba

All lagoon operations and discharges fall under *The Manitoba Environment Act* and must be licensed to operate. Lagoon operators usually follow a similar procedure in order to comply with their license requirements for discharge (generally these deal with BOD and coliform limits but are specific for each license). Prior to any lagoon discharge, the primary and secondary cells are isolated by closing the interconnecting valve between the two cells. Typically, the secondary cell remains isolated for a period of two to three weeks to allow for natural breakdown of organics and coliforms without the introduction of any new wastewater from the primary cell.

After this period, the secondary cell is sampled and will only be discharged if the laboratory results indicate that the effluent is within the license discharge limits. Otherwise the secondary cell will be re-sampled. Further treatment would have been on-going as turnaround time for results from the lab is usually between seven to ten days. Once the effluent meets license limits, the secondary cell will be discharged. After the release has been completed, the interconnecting valve between the primary and secondary cell is re-opened to provide storage capacity for the incoming wastewater. This cycle would be repeated for each discharge event. During discharge, department staff from Manitoba Conservation may monitor the effluent quality. The frequency of monitoring is variable from region to region and is dependent upon individual lagoon circumstances and history. Specific details for the lagoon operations in the Manitoba portion of the Basin have been summarized in section 6.7.2.

6.5 Environmental Impacts

Although properly constructed and operated lagoons generally provide high quality wastewater treatment, environmental impacts can occur when treated wastewater is released. For example:

- Bacteria may render downstream water unfit for drinking water supply, irrigation, or recreation uses.
- Minerals in the wastewater can affect the use of the receiving water for irrigation or livestock watering.
- Available nutrients such as phosphorous from a lagoon discharge may promote excessive growth of algae and weeds in waterways.
- Discharges of ammonia from a lagoon may be harmful to aquatic life, including fish because of the toxicity of the unionized ammonia form.
- Increased colour and turbidity (cloudy water) can impair the physical appearance of downstream water for some uses.
- Seepage (leakage) from lagoons can result in damage to land or groundwater.

6.6 Mechanical Wastewater Treatment Plants

Mechanical wastewater treatment plants consist of arrangements of mechanical devices and structures that treat wastewater within a matter of hours. They can be fairly compact and are thus suitable for larger centres. Although mechanical treatment systems require less space than lagoons, they are expensive to build and operate.

The H.M. Bailey Water Pollution Control Plant in Yorkton, commissioned in 1991, is the only mechanical treatment plant in the Saskatchewan portion of the Basin. The plant discharges treated wastewater on a daily basis, therefore, more diligent monitoring of the effluent and the receiving stream is required (see Table 6.2). Table 6.3 provides the mean seasonal water quality results for three monitoring stations on Yorkton Creek; Station 1: 1 mile upstream of the discharge; Station 2: 1 mile downstream of the discharge; and, Station 3: 10 miles downstream. The monitoring was done by the City of Yorkton during the period 1992 to 1999 as a requirement of the City's permit to operate sewage works. The parameters used in Table 6.1 are significant when assessing the impacts of a municipal wastewater discharge. Overall, the H.M. Bailey Plant met the requirements as specified by the province (Table 6.1) for secondary sewage treatment at a mechanical treatment plant.

As shown in Table 6.3, total coliform and fecal coliform counts at Station 1 ranged from 840 to 25,432 organisms per 100mL, and 64 to 458 organisms per 100 mL, respectively. The relatively high counts during summer at this station may be due to contamination from livestock operations or other sources. The total and fecal coliform counts increased dramatically at Station 2, as would be expected just below a wastewater discharge. However, by the time the effluent reached Station 3 there was a significant die-off of these bacteria to levels at least 90 percent less than measured at Station 2. Data presented in Table 2.4 for the Whitesand River indicate that this die-off continued downstream to where coliform counts ranged from only 10 to 40 organisms per

F2

100 mL at Highway No. 9. These counts were well below the surface water quality objectives for both contact and non-contact recreation.

The data for nutrient loadings from Table 6.3 indicate that the concentration of total nitrogen, total phosphorus, ammonia-nitrogen and nitrate-nitrogen downstream of the discharge are lowest in spring and highest in winter. Again, this is expected since nutrient concentrations are typically affected by the quantity of water flow in the system, with lower concentrations in spring and higher concentrations in winter under ice. The data also indicate that lower concentrations of nitrate-nitrogen and higher concentrations of ammonia-nitrogen during winter may be due to anaerobic conditions and conversion of nitrate to ammonia.

Table 6.2
Water Quality Results from 1992 to 1999 Presented as a Seasonal Average for Effluent of the Yorkton Sewage Treatment Plant

Parameters	Spring	Summer	Fall	Winter
Fecal Coliforms	24268	57029	159994	119912
Total Coliforms	118533	334830	255361	422870
NO_3NO_2	2.82	7.5	8.75	3.02
Ammonia	23.2	12.98	14.16	24.88
TKN	28.8	14.5	16.5	31.6
BOD	16.4	25.2	23.0	23.75
Total P	4.53	3.99	5.77	6.25
Ortho-P	3.69	2.93	4.87	4.99
Sodium	344.8	307.6	350.5	386.9
Sulphate	445.1	563.8	511.3	426.5
TDS	2108	2204	2159	2195
TSS	11.9	13.8	11.6	13.7

Expressed in mg/L

Table 6.3
Water Quality Results from 1992 to 1999 Presented as a Seasonal Average for Yorkton Creek Upstream and Downstream of the Yorkton Sewage Treatment Plant

Parameters	1.6 km upstream STP				1.6 km downstream STP				West of Ebenezer (16.1 km north of Yorkton)			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Fecal Coliforms	64	458	80		7276	16198	5318	199285	368	94	48	7383
Total Coliforms	11250	25432	840		43893	334041	330787	375750	1212	6556	1212	48471
NO_3NO_2	0.536	0.048	0.13		0.75	4	5.6	2.6	0.77	0.8675	2.1	1.45
Ammonia	0.82	0.06	0.19		2.48	5.37	11.4	24.9	0.675	0.53	1.51	19.27
TKN	3.16	2	2.41		4.98	8.53	10.95	31.5	3.04	2.64	6.01	37.17
BOD	7.01	3.1	2.48		9.15	12.7	8.5	12.6	6.8	3.86	5.29	9.2
Total P	0.6	0.2	0.19		2.4	2.14	3.69	6.59	0.85	1.28	1.55	7.8
Ortho-P	0.38	0.11	0.09		0.47	1.84	2.92	5.33	0.57	1.03	1.24	6.9
Sodium	55	76	94		61	201	252	403	117	148	234	472
Sulphate	133.5	302	387		152	462	473	399	190	353.6	445	480
TDS	514	925	107		571	1622	1777	2191	827	1221	1823	2800
TSS	20.7	7.6	10.3		24.3	10.5	15.1	11.6	20.9	18.1	20.5	14.9

Expressed in mg/L

6.7 Current Municipal Lagoons in the Basin

6.7.1 Saskatchewan

All population figures are taken from the Saskatchewan Municipal Affairs, Culture and Housing 1999 Municipal Directory.

1) Buchanan - Population 279, located at SE 4-31-06-W2, 2 cell system, allowed to discharge twice a year into Good Spirit Creek.
2) Calder - Population 106, located at NE 15-25-31-W1, 2 cell system, allowed to discharge twice a year into Calder Lake.
3) Canora - Population 2,208, located at NE 31-30-03-W2, 2 cell system, allowed to discharge twice a year into Whitesand River.
4) Churchbridge - Population 815, located at SE 18-22-32-W1 and NW 08-22-32-W1, 2 cell system, allowed to discharge twice a year into Deerhorn Creek.
5) Duck Mountain Provincial Park - Population unknown (seasonal), located at N ½ 21-30-30-W1 (Ministik/Core area), 2 cell system, allowed to discharge twice a year into marsh area located at NE 21-30-30-W1. Another lagoon is located at NW 13-31-30-W1 (Pickeral Point), 2 cell system, allowed to discharge into a surface drainage in the NW 13-31-30-W1.
6) Ebenezer - Population 166, located SW 25-27-04-W2, 2 cell system. Strictly an evaporation system which does not discharge unless in an emergency.
7) Good Spirit Provincial Park - Population unknown (seasonal), located at E 1/28-29-5-W2, 2 cell system. Primarily an evaporation system, however, also allowed to utilize effluent irrigation as a method of disposal if needed.
8) Hyas - Population 119, located at NE 06-34-02-W2, 2 cell system, allowed to discharge twice a year into a nearby slough.
9) Invermay - Population 295, located at NW 01-33-09-W2, 2 cell system, allowed to discharge twice a year into Saline Lake.
10) Jedburgh - Population 13, located at NE 36-26-08-W2, 2 cell system that dosen't discharge.
11) Kamsack - Population 2,264, located at NE 27-29-32-W1, 2 cell system, allowed to discharge twice a year into Assiniboine River.
12) Langenburg - Population 1,119, located at NE 26-21-31-W1, 2 cell system, allowed to discharge twice a year into Smith Creek.
13) MacNutt - Population 95, located at SE 22-24-31-W1, 2 cell system, intermittent discharge.
14) Margo - Population 127, located at NW 10-33-10-W2, 2 cell system, discharges into Margo Lake.
15) Melville - Population 4,646, located at NE 04-23-06-W2, a 4 cell system, allowed to discharge twice a year into Crescent Creek. Also allowed to utilize effluent irrigation to the golf course.
16) Preeceville - Population 1,148, located at SE 27-34-05-W2, 2 cell system, allowed to discharge twice a year into the Assiniboine River.
17) Rama - Population 99, located at SW 24-32-08-W2, 1 cell system, discharges into slough on village property.

18) Rhein - Population 197, located at SW 26-27-2-W2, 2 cell system, allowed to discharge twice a year into slough on same location.
19) Saltcoats - Population 531, located at NW 36-23-02-W2, 2 cell system, allowed to discharge twice a year into natural drainage course.
20) Sheho - Population 181, located at NW 10-30-09-W2, 2 cell system, allowed to discharge twice a year into Elbow Creek.
21) Spy Hill - Population 264, located at NE 02-19-31-W1, 2 cell system, allowed to discharge twice a year into Deerhorn Creek.
22) Stenen - Population 100, located at SE 09-34-03-W1, anerobic 2 small treatment cells, allowed to discharge twice a year.
23) Sturgis - Population 684, located at NW 21-34-04-W2, 2 cell system, allowed to discharge twice a year into the Assiniboine River.
24) Theodore - Population 434, located at SW 15-28-07-W2, 2 cell system, allowed to discharge twice a year into Theodore Lake (slough).
25) Togo - Population 138, located at NE 02-28-30-W1, 2 cell system which dosen't discharge.
26) Veregin - Population 90, located at SW 10-30-01-W2, 2 cell system, doesn't discharge.
27) Wroxton - Population 50, located at NW 03-26-32-W1, 2 cell system, doesn't discharge.
28) Yorkton - Population 15,154, Mechanical treatment system, constant discharge into Yorkton Creek.

6.7.2 Manitoba

There are five municipal lagoons currently operating within the Manitoba portion of the Upper Assiniboine River Basin. A brief synopsis of each lagoon is provided outlining background, monitoring, and enforcement issues.

1) Binscarth - the Town of Binscarth currently operates a lagoon located in the NW 10-19-28 W3. This lagoon was established 35 years ago and issued a license in 1965 by the Provincial Sanitary Control Commission (PSCC). Conditions of the license are very general. Periods of discharge to Silver Creek are restricted to occur between May 15 to November 1. There are no specific discharge restrictions with respect to coliform bacteria or biological oxygen demand. Instead, it broadly states that effluent discharge should not create a nuisance either in Silver Creek or adjacent drainage course.

   PSCC licenses were not validated in the revised *Environment Act* of 1988. This change within the Act essentially required all new and existing lagoons to submit an environmental impact assessment proposal prior to being issued a new license. The Town of Binscarth has only recently applied for a new license as part of their proposal to remedy seepage losses from their secondary cell. Historically, rates of seepage loss through the bottom of the secondary cell have been of sufficient magnitude that it was often unnecessary to discharge effluent to Silver Creek.

2) Inglis - the lagoon currently servicing the Town of Inglis is located in SW 6-23-27 W3. This lagoon was built 34 years ago and issued a license in 1966 by the PSCC. The effluent discharge route is via Bear Creek, which flows into the Shell River. Again, conditions of the discharge are very general. The license requires that effluent discharge can only occur from the period between May 15 to June 15 and within the period from September 15 to November 1. The clause that "effluent discharge should not create a nuisance either in Bear Creek or adjacent drainage course" is also present.

Similar to Binscarth, this lagoon has officially operated without a license since 1988, and has been following the conditions of the original license. Currently, the Town of Inglis is in the final process of receiving a new license after submitting a proposal to expand the capacity of the lagoon's secondary cell.

3) Angusville - the Angusville lagoon is located in NE 21-20-26 W3. The lagoon was established 28 years ago and is still operating under the license issued by the Clean Environment Commission in 1972. License specifications only allow effluent discharged to a slough south of the lagoons to occur between May 15 to November 1. License requirements also stipulate that prior to discharge, the effluent quality must not have a BOD concentration of greater than 30 mg/L or a level of total coliform bacteria greater than 1500 organisms per 100 mL.

4) Russell - the municipal lagoon servicing the Town of Russell is located in the SE 4-21 28 W3. Discharge from the lagoon is directed south along an intermittent drainage channel to Silver Creek, approximately 24 km south. Silver Creek flows south and empties into the Assiniboine River southwest of Binscarth.

The lagoon was established 35 years ago and operated under PSCC license until 1978. The new license developed under an order from the Clean Environment Commission is still in effect today. Conditions of the license allow effluent discharge to occur during the year from May 15 to November 1. The license also specifies that before discharging effluent, the quality of the BOD concentration must be no greater than 30 mg/L and the total coliform bacteria content must be no greater than 1500 organisms per 100 mL.

Past enforcement issues have been related with the failure of the lagoon operator to ensure sampling was conducted for total coliform prior to release and with the effluent failing to meet the total coliform limits. BOD results have met the license limits. Currently the Town is dealing with a berm failure along the north cell that occurred in the spring of 1999, although this has been temporarily repaired. The Town is in the process of reviewing and providing a more permanent solution to the problem.

5) Roblin - the original lagoon site was located close to Roblin in NW 5-26-28 W3. This lagoon operated from 1959 to 1981 with effluent discharge directed to West Goose Lake. The current Roblin lagoon was established 19 years ago and is located in SW 28-25-28 W3. It was licensed under an order by the Clean Environment Commission and specified conditions that allowed for discharge of effluent via land irrigation application. The

license specified conditions that allowed for emergency discharge to the Shell River in the event that effluent discharge could not occur to the irrigated land.

The current active license, developed in 1998, stipulates conditions that permit effluent discharge either to a land application or a constructed wetland. The constructed wetland was added to the system because of the diminishing capacity of the irrigated land to receive effluent, particularly during wet years. Once the wetland is fully operable, any flow-through discharge to the Shell River will be of high quality, with reduced nutrients and organic loading.

License requirements for discharge from the wetlands into the Shell River specify concentration limits for un-ionized ammonia not to exceed 0.05 mg/L and for total phosphorous not to exceed 0.15 mg/L. A standard clause dealing with fecal coliform (200 organisms per 100 mL), total coliform (1500 organisms per 100 mL), and BOD (30 mg/L) concentrations are also included. Other clauses limit the amount of mineral concentration that must be met for discharge. These include Al, As, Be, Bo, Cd Co, Cr, Cu, F, Fe, Li Mn, Mo, Hg, Ni, Pb, Se, V, Zn.

License conditions also specify that effluent discharge from the lagoons to either the land application or wetlands can only occur from May 1 to November 1. At the present time, while the wetland plants are developing, suspensions of the license requirement for discharge to the Shell River have been granted to the Town when requested. Requests have only been granted when the effluent quality met BOD concentrations of 30 mg/L or less, fecal coliform concentrations of 200 organisms or less, total coliform concentrations of 1500 organisms or less, and chlorine residuals of 11 micrograms or less.

6.8 Summary

In summary, effective wastewater treatment involves proper planning, design, construction, operation, monitoring, and an investment of hundreds of thousands of dollars by each community. Whether treatment is provided by lagoons or mechanical wastewater treatment plants, a coordinated effort of community officials, operators, engineers, and the provincial government ensures that systems work efficiently and minimize impacts on the health and safety of the residents and on the environment.

6.9 Recommendations

There is no present evidence to suggest that wastewater release or seepage is a major concern in the Basin. More extensive studies and monitoring are required to determine any long-term effects.

6.10 Municipal Alternatives...a Case Study
The Town of Roblin's Alternate Effluent Management System

The Town of Roblin, a small community of 2100 people located in the northeast corner of the Basin, has taken a different approach to sewage disposal than most urban centres in the Upper Assiniboine River Basin. While the Town still relies on a typical lagoon system to treat the effluent to provincial discharge standards, they have chosen alternative methods of managing the treated effluent and have developed a system unlike any other in the Basin.

During the redevelopment of their lagoon system during the late 1970s, the Town decided rather than discharging the lagoon cells into the Shell River, which empties into Lake of the Prairies, they would utilize all of the liquid produced to irrigate crop land. During the 1980s, when dry weather was prevalent, the liquid was put to good use in the irrigation of alfalfa crops. The additional liquid, with its natural nutrient loading, drastically increased the amount of crop produced and harvested. However, with the wet weather in the 1990s, problems were encountered properly utilizing all the effluent from the Town. During this time the crops needed much less liquid for growth, while the amount of liquid being produced increased by more than 30 percent. In order to properly manage the total amount of effluent produced during the wetter years, additional alternatives were required. As a result, an investigation into various options available was initiated. Throughout the research process, a large number of different options were examined:

1) Snowfluent - a process in which effluent is turned into snow with the use of snow making equipment. As the effluent is sprayed into the air and freezes, all bacteria are killed and the minerals precipitate out during the process. Concern: a salinity problem may occur on the land used for the processing of the effluent due to the minerals left behind following the spring melt and concerns existed regarding the runoff liquid.

2) Increase Irrigation Land Base - during wet years, the additional land base should be sufficient to properly utilize all the effluent. Concern: during dry cycles, insufficient effluent would be available to maximize production on the total land base served.

3) Provide Carryover Storage Capacity - installation of additional holding cell(s) to carry over excess liquid from one year to the next when wet weather is encountered. Concern: this would only provide one year of grace as the held liquid would still have to be utilized the following year for irrigation. Examination of the weather cycles in the area indicated these wet/dry cycles usually last for a much longer periods of time.

4) Split disposal - utilize as much effluent as possible through the irrigation process with the remaining effluent discharging to the local river. Concern: this would create some impact on the local water bodies and be of concern to the local population.

5) Reduce Effluent Production - reducing or eliminating the invasion of groundwater into the sewer system would reduce the amount of effluent being produced and, therefore, the

amount of effluent to be disposed of in the irrigation process. Concern: while this could be part of an overall management process of the effluent system, reduction of infiltration water alone would not be sufficient to meet the needs of the Town.

6) Constructed Wetlands - construction of a wetland system could be used to provide additional treatment to a large portion of the effluent with little or no discharges required while still utilizing the major portion for crop production. Concern: cost of construction and complexity of establishing and maintaining proper plant growth.

Each option examined had its own advantages and disadvantages. In the end, constructed wetlands appeared to have the most advantages of the various alternatives investigated. During dry years, liquid could easily be diverted to the irrigation site as required for plant growth. During years with above normal precipitation, excess liquid could be handled through the wetlands. In the extreme case, if the amount of precipitation is excessive, and too much liquid is produced to be properly processed, a discharge to the river would be required. If this situation should occur, the quality of liquid from the wetlands would be much superior and would not create undue nutrient loading to the Shell River or to Lake of the Prairies. Due to the versatility of the system, it was decided to install an 18-hectare (40 acre) constructed wetland, along with other alternatives, and integrate them into the existing lagoon-irrigation system.

6.10.1 Wetlands Design and Operation

A constructed wetland is basically a marsh that has been designed, built and operated for a particular purpose. In most instances, the site utilized was not previously a wetland and some earth work is required to build the required berms and cells. In Roblin's case, the wetlands are composed of four different cells located on a portion of the 36-hectare (80 acre) parcel of land located adjacent to the existing lagoons. Each cell is seeded down to a variety of reed, sedge, rush, and other marsh type plants such as cattails and bulrushes.

As the pre-treated liquid slowly passes through the various cells, the natural purification process continues as bacteria further break down any remaining organic matter. In addition, the floating and rooted plants remove much of the nutrient loading from the liquid, further processing it and greatly improving the water quality.

In order to properly optimize plant growth and insure longevity, the liquid levels within the cells are maintained at an optimum level of 30 cm. Due to the shallow nature of the liquid, the area covered, and the large mass of plants present, most of the liquid is lost to evaporation and plant evapo-transpiration. The Roblin wetlands system is designed to process 13,600 m^3 (30 million gallons) of pre-treated effluent each year, which is approximately 50 percent of the Town's total effluent production. It is anticipated that in an average to slightly wet year, no discharges from the wetlands will be required.

Figure 6.1
Photograph of the Signage for the Town of Roblin's Alternative Management System

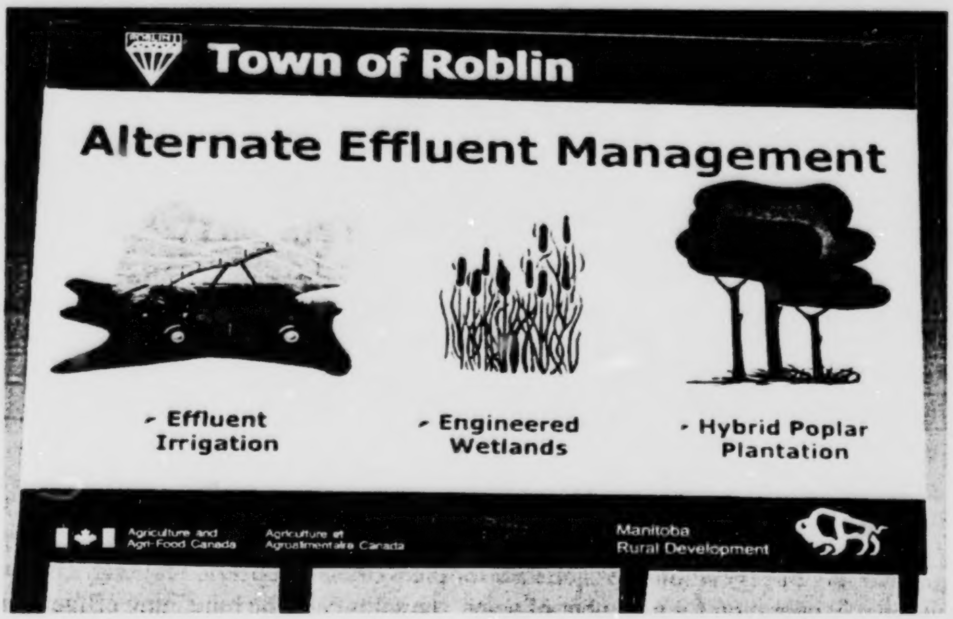

Town of Roblin
Alternate Effluent Management
Effluent Irrigation
Engineered Wetlands
Hybrid Poplar Plantation
Agriculture and Agri-Food Canada
Agriculture et Agroalimentaire Canada
Manitoba Rural Development

Figure 6.2
Photograph of the Roblin Lagoon, Showing Cells 1 and 2

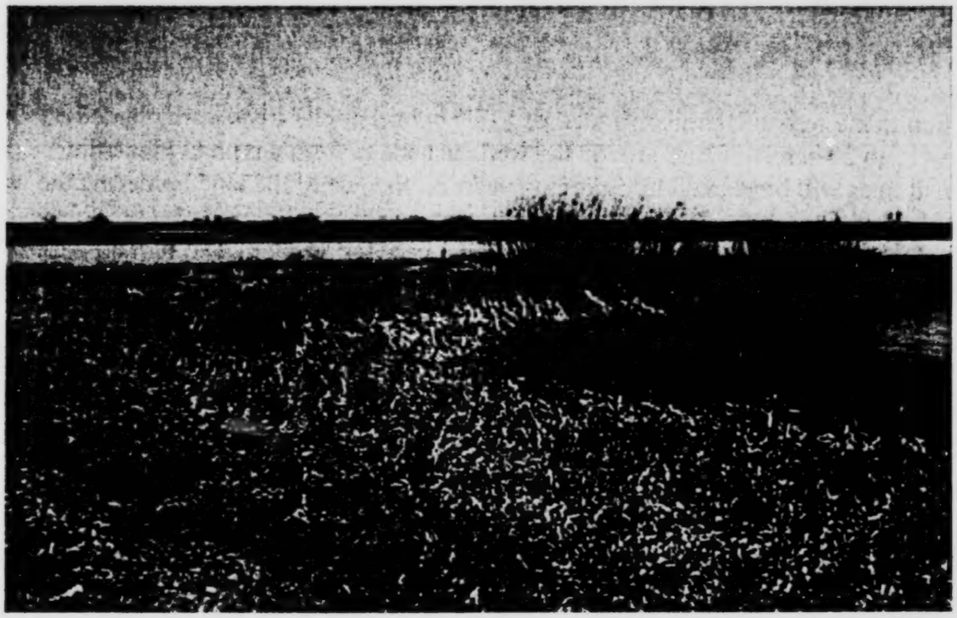


Table 6.4 shows the average nutrient reduction achieved by wetlands of this nature. The Roblin treated effluent quality is much better than the stated averages, with levels of: BOD_5 at 10-15; TN at 0.01-9.0; and TP at 2.3-3.5.

Table 6.4
Average Nutrient Reduction in Wetlands
(North American Wetlands Conservation Council of Canada 1994)

Parameter	In (mg/L)	Out (mg/L)	Removal Efficiency (%)
5-day Bio-chemical oxygen demand (BOD_5)	38.8	10.5	73
Total Suspended Solids (TSS)	49.1	15.3	69
Ammonia Nitrogen (NH_3-N)	7.5	4.2	44
Total Nitrogen (TN)	14	5	64
Total Phosphorous (TP)	4.2	1.9	55

The main disadvantage to wetlands is that unlike many other projects or sewage works installed, newly constructed wetlands can take several years and a great deal of work before the proper amount and variety of vegetation is established for the wetland to operate properly. Once the cells have been in operation for a number of years, the salinity of the remaining effluent must be monitored very carefully due to the amount of evaporation that takes place. In addition, great care must be taken to insure natural predators, such as muskrats, are controlled and the site must be properly managed to prevent permanent damage from occurring to the plant growth and dike wall structures.

6.10.2 Hybrid Poplar Trees

In addition to the wetlands project, a total of 5,000 hybrid poplar trees were planted on 7 to 9 hectares (15 to 20 acres) of land around the wetland cells to form a type of plantation. Additional trees will be planted in upcoming years on the rest of the land bordering the wetlands. These hybrid poplar trees will not only provide seepage control, but will also provide an additional use for the effluent. Since these trees are very fast growing and require a great deal of liquid for growth, large amounts of effluent can be used from the wetlands for irrigating the trees. Once established, the liquid requirements will increase even more due to the amount of evapotranspiration from the vegetative canopy. In addition to the uptake of additional liquid, the trees will provide excellent wildlife habitat and help stabilize the soil. Hybrid poplar trees are extremely rapid growing and will reach a height of 9 metres and mature within 10 years. The trees may then be harvested and sold for further processing into a variety of wood products.

6.10.3 Effluent Production Management

6.10.3.1 High Water Usage

A water and sewer audit carried out indicated the per-capita usage of water within the Town was much higher than normal. Given the size and population of Roblin, the amount of effluent produced yearly is approximately 250 percent of that produced by towns of similar size. As a result, the Town has embarked on a public education and water conservation program in an attempt to reduce the average water consumption. Part of this involved the supply and installation of toilet dams and flow restrictions in many of the homes. After the first phase of the "water use reduction" program, approximately 50 percent of the homes had installed the water saving devices. Further promotions are planned to increase participation among the Town residents and further reduce water consumption. The Town has also initiated the replacement of some water lines in an attempt to improve the quality of water and reduce the need for unnecessary conditioning equipment in each house.

6.10.3.2 Groundwater Infiltration

While the wetter weather created more processed effluent for disposal, the amount of increase was not proportional to the increase in yearly rainfall. During a two-year period, the amount of effluent produced rose from less than 50,000,000 gallons to more than 65,000,000 gallons yearly. Further investigation revealed that a surficial gravel formation in one portion of the Town, was a major cause for the large increase in effluent being produced. Due to local topography, most of the drainage around this area flows into this formation and becomes trapped. During wet years, the water table in this area can rise to nearly ground level. While the Town of Roblin had replaced many of the sewer lines in this area to eliminate any groundwater invading the lines, the problem was only postponed. The water level continued to rise until it reached the level of the weeping tiles in the nearby homes. At this point, a great deal of the groundwater drains off through the home weeping tiles and into the sewer collection system placing a large strain on the lagoon and disposal system. The Town is presently investigating and collecting data to better understand the situation and will be considering various options for controlling this groundwater invasion. By controlling the excess infiltration of groundwater into the sewer system, the present demand on the lagoon and effluent management system will be greatly reduced.

6.10.3.3 Effluent Quality

The major drawback to any action taken to reduce the level of groundwater infiltration into the sewer system will be the deterioration of the quality of effluent being produced. Without the additional liquid, acting to dilute the treated effluent, the mineral content of the effluent will increase. This can create problems with increased soil salinity of the irrigation and wetland sites. In an attempt to reduce the mineral content (chloride levels) the Town is embarking on a program of voluntary controls for in-house water softeners. Previous experience in other centres in the province has shown that most domestic softeners are not set for the most economical use of salt. By simply resetting the softeners, the amount of salt ending up in the sewer system can be reduced by approximately 30 percent without affecting the performance of the softeners. This will not only save the homeowner money, but will also have a positive affect on maintaining the quality of the effluent being produced and extend the useful lifetime of the irrigation and wetland sites.

6.10.4 Summary

Overall, the inclusion of a wetland and woodlot to the already existing irrigation system, along with the future actions to reduce effluent production, will have many positive benefits for the Town of Roblin. Not only will these efforts greatly assist in the Town's ability to properly manage the effluent during the different weather cycles, but will continue to limit the amount of nutrients being discharged into the local watershed and eventually into Lake of the Prairies. This will assist in maintaining the water quality in the lake for not only fish and wildlife, but also the local population and tourists.

The constructed wetlands and hybrid poplar plantation will also provide not only renewable and saleable wood products in the future, but will also provide a large area of ideal habitat for wildlife and birds. The Town is hoping to establish a nature and educational walk through the wetlands/plantation area for tourists and students. The local school has already expressed interest in utilizing the area for classroom education and participation. As a result of the Town's commitment and efforts over the years, other towns are presently looking at Roblin's example and are seriously considering the various possibilities open to them in the proper management of their treated effluent.

6.10.5 Conclusion

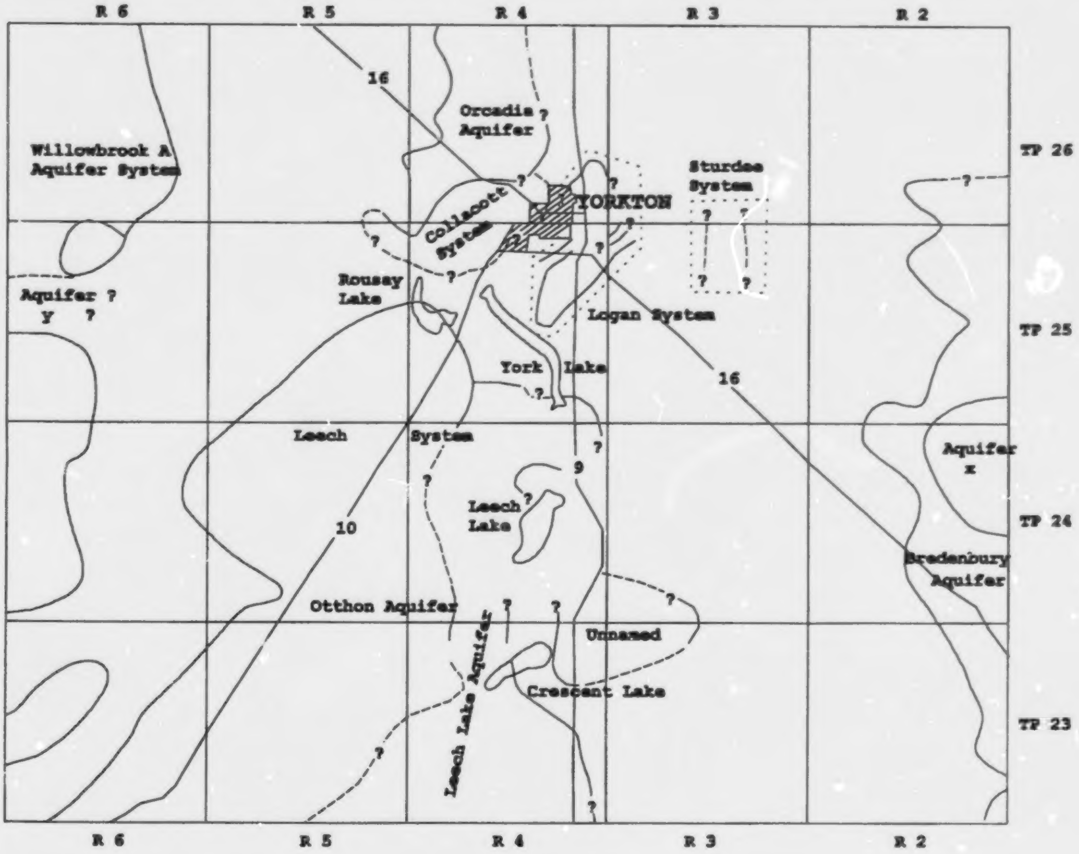
With a little thought and ingenuity, many towns can begin to utilize their effluent for production of goods, while reducing the impact on our country's water bodies from lagoon discharges. This will extend the useful lifetime of the rivers and lakes and prolong their enjoyment for our citizens and tourists, while ensuring that the purity of the water supplies remains high.

7 Groundwater Protection

7.1 Introduction

Throughout the Upper Assiniboine River Basin, groundwater plays an integral part in everyone's daily life. Due to existing geology in the area, groundwater is utilized as the major source of potable water for numerous cities, towns, villages, and individuals scattered throughout the region. While some of these groundwater sources are very shallow, others are fairly deep. The susceptibility of each aquifer (water bearing formation) to contamination varies greatly and is dependant on the type and amount of deposits or overburden covering the water table.

Figure 7.1
Major Aquifers Located in the Yorkton Area


R 6
R 5
R 4
R 3
R 2
TP 26
TP 25
TP 24
TP 23
16
Orcadia Aquifer
Willowbrook A Aquifer System
YORKTON
Sturdee System
Collacott System
Rousay Lake
Aquifer Y
Logan System
York Lake
16
Leech System
Aquifer X
9
Leech Lake
10
Bredenbury Aquifer
Otthon Aquifer
Unnamed
Leech Lake Aquifer
Crescent Lake
R 6
R 5
R 4
R 3
R 2

7.2 Legislation

The provinces of Saskatchewan and Manitoba both have various acts, policies, regulations, and guidelines to develop, maintain and protect groundwater in the province for the protection of public health, as well as the following purposes:

- Preservation and protection of groundwater supplies;
- Sustainable development of groundwater for domestic, agricultural, industrial, and other economic activities;
- Preservation of water quality;
- Protection of public health; and
- Municipal and domestic water supplies.

7.2.1 Saskatchewan

7.2.1.1 *The Water Corporation Act*

The Act empowers and mandates the corporation to undertake numerous responsibilities to manage, protect, and develop the provincial water resource including the licensing required to divert water from a groundwater source.

7.2.1.2 *The Groundwater Conservation Act*

The purpose of this Act is to obtain logs of wells drilled and information on formation and materials during the drilling operations. This information is utilized in various geological studies and to provide for the conservation, development, and utilization of groundwater resources and prevent pollution and contamination of groundwater.

7.2.1.3 *The Environmental Management and Protection Act* (EMPA)

The EMPA governs pollution control in the province of Saskatchewan dealing specifically with water pollution, industrial effluent works, sewage works, and regulation of all matters concerning water quality. The Act establishes permit requirements, and procedures of permit acquisition for discharge of contaminants that might cause a change in water quality or water pollution.

7.2.1.4 *The Public Health Act*

The Public Health Act governs the operation of all water systems used for human consumption and controls all aspects of the water source, treatment, distribution system, sampling requirements, and operation.

7.2.1.5 *The Agricultural Operations Act*

The Agriculture Operations Act balances environmental responsibilities with the realities of agriculture protection. A major provision of the Act is the protection of groundwater and surface water by proper management of manure and animal waste.

7.2.1.6 Other Guidelines/Regulations

- *The Irrigation Act*
- The Water Pollution Control and Water Works Regulations
- The Environmental Spills Regulations

7.2.2 Manitoba

7.2.2.1 *The Groundwater and Well Water Act*

Manitoba *Groundwater and Well Water Act* was established to insure all well drillers operating in the province are licensed and the installation of all water wells meet certain development criteria, well information is recorded, flowing wells are sealed, precautions are taken to insure pollution of aquifers does not take place, and dry or abandoned wells are properly sealed.

7.2.2.2 *The Water Rights Act*

The Manitoba Water Rights Act requires that all wells diverting more than 25,000 liters per day be licensed to insure proper allocation and distribution of available aquifer capacities and to limit any inter-well interference or aquifer dewatering by various water users of an aquifer. Water is allocated on a "first in time, first in right" principal.

7.2.2.3 *The Environmental Act*

The Manitoba *Environmental Act* requires all classes of development to undergo an environmental assessment and licensing process. This would include operations such as landfills, lagoons, large livestock operations, industrial sites etc. Construction plans, operational guidelines, and sampling requirements would all be specified in the license in order to mitigate any potential impacts to groundwater quality and the environment.

7.2.2.4 *The Public Health Act*

The Public Health Act provides regulations and orders respecting; sewer treatment systems; construction, maintenance and purification of water systems and supplies; and preventing pollution of wells, underground waters and springs.

7.2.2.5 Other Guidelines/Regulations

- The Designated Flood Area Regulation
- *The Water Supply Commission Act*
- *The Manitoba Water Services Board Act*
- *The Conservation Districts Act*

7.3 Aquifer Vulnerability

With shallow groundwater formations, such as the Collacott and Logan aquifer systems near Yorkton, the water table is quite close to the surface and open to a variety of possible contaminants. The Sturdee aquifer system is also sensitive to contaminants due to the permeability of the overlying material. These types of aquifers are referred to as 'unconfined' or 'vulnerable' aquifers since they do not have a good protective layer of clay or till (bolder clay) between the water table and the surface of the ground. In some cases, the water level can come so close to the surface that groundwater can form sloughs or lakes as the ground elevation drops below the surface of the water table. Depending on how much the ground elevation fluctuates, these areas may be permanently inundated with water or may only become evident during periods of high water table.

With this type of aquifer, any surface activity has the potential to impact on the quality of the groundwater. Since these formations do not have sufficient protective covering of clay or other impermeable material, there is little to stop the downward migration of any pollutant once it is past the upper root zone of soil. These types of aquifers are often most at risk for contamination with the accumulation of nitrates, fuels, pesticides (herbicides, insecticides, fungicides, or rodenticides) or a multitude of other contaminants.

Of additional concern is the interaction of surface watercourses and groundwater and their effects on the aquifers. For example, during the mid-1990s, the Logan east aquifer developed a colour problem that was the result of naturally induced recharge from Yorkton Creek. The Sturdee aquifer system may be connected to the overlaying watercourses and, therefore, is very susceptible to contamination from pollutants being carried in the surface creeks or streams.

The alluvial fill type aquifers, commonly found along river channels, are also extremely susceptible to contamination as they recharge directly from the river and are susceptible to all the various contaminants carried by the river. This not only includes fertilizers, pesticides, fuels, and other contaminants washed off fields and urban residential areas, but also sewage and lagoon discharges or any land development that occurs upstream.

In other areas of the Basin, aquifers are deeper in nature and are often protected with a thick layer of impervious materials such as clay or till. In some instances, the water in the aquifer is under some pressure and will tend to rise up the well casing once this layer is penetrated during the drilling operation. Since these confined aquifers are not as open to contamination, they are generally assumed to be less vulnerable to surface activity.

Despite having this natural protection, many of these wells are found to be contaminated to some extent each year. This contamination generally occurs through the well itself, around the casing or through an old or improperly abandoned well, and is often a direct result of the lack of knowledge and poor management practices by the owner.

7.4 Well Abandonment

One of the greatest threats to the integrity of our groundwater, regardless of whether it is from a confined or unconfined aquifer, is through the well itself. While the chances of contamination around or through the existing well can be easily prevented, many wells become contaminated each year due to owner error or lack of knowledge.

Even more of a concern, is the number of old and abandoned wells existing throughout the country today. Given that wells have an average useful lifetime of 15 to 30 years, and wells have been drilled in this country since the late 1800s, a great number of wells have been drilled and subsequently replaced over the years. In Manitoba alone, it is estimated there are 10,000 wells that have not been properly abandoned and sealed to prevent contamination.

The necessity to properly seal old abandoned wells became evident during the "Flood of the Century" around Winnipeg in 1998 when a great number of abandoned wells were found to be open and were allowing huge amounts of contaminated flood water to invade the local aquifer. As a result, many months of work were needed to clean up the problem created by these old wells. The amount of permanent damage sustained to the aquifer is unknown. While this is the extreme case, the majority of well contamination occurring in confined aquifers is a result of poorly sealed or abandoned wells.

Both Saskatchewan and Manitoba have guidelines for the proper abandonment and sealing of wells, but the lack of enforcement has resulted in the existence of a great number of abandoned wells that provide a direct path for contaminants to enter and greatly impact an aquifer.

7.5 Contaminants

There are a great number of elements and compounds that can contaminate a groundwater source. In the farming community, the most common sign of contamination is a build up of nitrates in the water supply. The nitrates are commonly a result of excess nitrogen from fertilizers or manure leaching down past the plant root zone. Once past the root zone, they continue their downward movement with water until an impervious layer of soil or a water table is encountered.

This problem is very common on sandy or course-textured soils overlaying a shallow unconfined aquifer. Unfortunately, because these soils are not well suited to crop production, many livestock operations were developed in these areas compounding the nitrate contamination problem. In addition to nitrates, pesticides are an ever increasing concern to groundwater contamination. These chemicals are normally very water soluble and can easily wash down through the soil and accumulate in the water table.

The farming community is not the only area of concern. Urban centres can also add to the groundwater contamination problem due to the larger concentration of people, vehicles, and industries in one location. The large amount of fertilizers and pesticides used on lawns, salt on streets, and chemicals, fuels, and waste from businesses and industries have the potential to impact groundwater and surface water supplies through runoff or infiltration.

Due to the services provided, the urban centres must also deal with a large sewer collection and treatment system. While these sewage treatment systems have a major potential to cause contamination, their design, construction and operation are carefully monitored and regulated by provincial agencies.

7.6 Groundwater Management

The management of groundwater resources is the responsibility of the provinces and is commonly shared between several different agencies within each province. The assessment, management, and allocation of groundwater resources are the sole responsibility of one agency in each province, while water quality and potability are the responsibility of various agencies in each province.

Aquifer investigation, mapping, and identification have been carried out in both provinces by Sask Water and Manitoba Conservation. The aquifer boundaries and numerous small surficial deposits are not well defined. While well drill logs and other information are constantly being amassed and recorded to increase the aquifer database in each province, present funding limitations and higher priorities limit the more intense investigation needed for more exact mapping of many of the aquifers throughout the area. While some data are gathered on general water quality by this sector of the government, specific tests for pesticides and other potential contaminants are not generally carried out.

Some work has been carried out to map the potential for groundwater pollution of aquifers in one portion of the Basin. Since the potential for contamination is directly related to the amount and type of overburden above a fresh water aquifer, anything with less than 5 to 6 metres of clay, till, or other low-permeable materials is normally considered a "Pollution Hazard Zone".

It is the responsibility of the health and environmental agencies to monitor problems with water quality as it pertains to human health concerns. If a problem occurs that indicates a contamination concern, it is the responsibility of these agencies to take corrective steps and possibly enact the necessary regulations to prevent further contamination. While various agencies collect water quality information, there seems to be little integrated database management.

7.7 Groundwater Protection

Regulation and enforcement, coupled with public education, are generally used to protect groundwater from contamination. The regulations protecting the aquifers usually come about as a response to a problem rather than a forward-looking policy that prevents contamination in the first place.

At present, regulations are generally in place to prevent contamination from major "point source" potential contaminants. As an example, regulations exist regarding the placement, construction, and operation for projects such as waste disposal sites, municipal lagoons, fuel stations, farm manure storage sites, and a multitude of other collection and disposal systems.

Until groundwater contamination in the Basin is better understood, it is difficult to develop and justify a regulatory and enforcement system beyond the existing legal structure. Unfortunately, waiting until there has been sufficient groundwater contamination to justify regulations and enforcement does not adequately protect the current status of our groundwater.

Rather than relying only on regulations to protect the groundwater, public awareness, education programs, and incentives are methods that must be utilized if groundwater quality is to be maintained. As the public learns of the susceptibility of aquifers to contamination and how easily it can occur, they begin to understand the consequences of their everyday actions.

In order to be successful, public education approaches for a specific audience, such as agricultural producers, should be comprehensive, straightforward and related to existing farm management practices. As an example, Best Management Practices (BMPs) is a method of communicating environmentally favourable choices to producers. BMPs are those practices developed for a particular industry, such as agriculture, to protect the environment and long-term sustainability of the industry. For best results, BMPs should be developed with co-operation from all parties involved in a particular industry. Some of the recommendations included to prevent leaching of nitrogen into the water table include matching the nitrogen inputs to the cropping needs, not applying nitrogen to coarse textured soils in the fall, and analysing soil for nutrient content prior to fertilizer and manure applications.

Groundwater protection recognizes that prevention is the only effective approach to dealing with the potential for groundwater contamination. Once groundwater supplies are contaminated, remediation is often difficult, time consuming and expensive. Contamination that has occurred through leaching may not only require the source of contamination to be removed, but also the removal of the overlying soils through which the contaminant percolated. Methods for protecting groundwater supplies include proper well siting and construction, protection from potential contaminants in the recharge area, adopting beneficial management practices to reduce non-point contamination from agricultural sources, monitoring, and the need to properly decommission and seal unused or abandoned wells.

7.8 Monitoring

Monitoring and analysis of water quality throughout all the aquifers in the Basin is an expensive and time-consuming activity that is difficult to undertake given the current fiscal restraints being encountered. Any extensive monitoring that is undertaken should be concentrated in those areas most susceptible to contamination.

One important component of monitoring is the data analysis to identify water quality changes. Once sufficient data has been collected at regular intervals, trend analysis of variables can be carried out. This information, combined with modeling of the baseline conditions, can provide sufficient information to change the regulatory systems or implement appropriate public education before significant negative water quality changes occur. At the very least, samples should be obtained in areas of concern for chemical changes such as pesticides to establish a baseline for future comparisons.

Monitoring of groundwater supplies and some groundwater mapping have been undertaken to a limited extent in the Basin. In 1996, a small survey of 23 shallow wells was conducted for ADD Districts 12 and 13 by Clifton Associates Ltd., SERM, and PFRA with funding from the Canada-Saskatchewan Agriculture Green Plan Agreement. ADD Districts 12 and 13 are centered around Yorkton and Melville respectively. Groundwater quality within the area was very good, despite being quite variable. In early September 1996, 23 "worst case scenario" wells were sampled. The parameters most commonly found that exceeded applicable guidelines were: nitrates (as NO_3), sulphate, and total hardness (detected in 9 out of 23 wells). Nitrates are typically a result of human activities relating to point source contamination from animal or human wastes and direct entry of nitrogen based fertilizers into the well, whereas sulphates and total hardness occur naturally. The study reported that non-point contamination of aquifers with nitrate from nitrogen-based fertilizers is unlikely, except in areas where intensive agricultural production under irrigation is practiced. Nitrates are very mobile in groundwater and are known to dissipate with depth in an aquifer, although rates of dissipation vary widely depending upon temperature and other factors. The study also noted that because these wells were "worst case scenario" (i.e., wells with an extremely high contamination potential), random sampling would likely produce results with significantly less nitrate concentrations. Nitrate levels exceeding 45 mg/L pose a risk to the health of infants by causing the condition known as "blue baby syndrome".

Pesticides were detected in two of the 23 wells. However, the detection levels were 1,000 times lower than the Maximum Acceptable Concentration (MAC) specified by SERM's Municipal Drinking Water Quality Objectives. The pesticides detected were Dicamba (Banvel), MCPA and Atrazine. The "Shallow Groundwater Quality Survey for ADD Districts #12 and #13" was part of a larger province-wide study involving seven ADD Districts, in which a total of 184 shallow wells were screened from July to September in 1996, for 13 pesticides, major ions, and physical properties. Of all of the participating ADD Districts, ADD Districts #12 and #13 had the lowest percentage of wells with detections.

7.9 Summary

While groundwater plays an important part in the everyday life of the majority of the population throughout the Basin, many of the major aquifers in this area are vulnerable to contamination by surface activities. Even deeper formations, that are normally considered safe, are susceptible to contamination if precautions are not taken. Old wells are a major concern if they are not properly abandoned, as they can be a major factor in allowing contaminants to enter the water bearing formation.

The management of groundwater throughout the area is the responsibility of the provincial governments and is generally split between a number of agencies within each province. While each agency compiles large amounts of data regarding the different aspects of groundwater quality and quantity each year, there is little integrated database management. As a result, much of the information regarding availability and water quality is lacking continuity and can be difficult to obtain.

While it is known that pollution is occurring, even though some regulations are in place for protection of this vital resource, more work must be carried out to limit the occurrences of contamination and their effects. Monitoring of groundwater, particularly in the most sensitive areas, must be implemented and carried out in order to track the changes occurring to the water formations. Without long-term monitoring, it will be impossible to adequately protect our groundwater in the future since changes will not be detected until contamination is widespread.

The long-term potential for groundwater quality in the Upper Assiniboine River Basin, as with the rest of the Prairies, is that it may degrade from its current level as a result of human activity. To what extent and how soon this may occur is impossible to predict given the large number of variables present. The future of our groundwater quality is not only the responsibility of the various government departments, but also of every person living in the Basin.

A brochure entitled "Water Quality in the Upper Assiniboine River Basin" was developed as part of this study. It incorporates information on groundwater protection and is included in Appendix V of this report.

7.10 Recommendations

1) Initiate a public education program on proper well and aquifer management to protect our groundwater formations from contamination.

2) Implement and enforce proper well abandonment policies when new wells are installed and actively seal existing abandoned wells to reduce the chances of contamination.

3) Better define the outer limits of the various aquifers in the region, with emphasis on unconfined or vulnerable aquifers.

4) Develop "Pollution Hazardous Zone" maps of the various aquifers in the region. These maps could then be utilized by local governments and planners as a guide in the future development of the area.

5) Develop and promote Best Management Practices (BMPs) for agriculture and other industries throughout the area with emphasis on groundwater protection.

6) Encourage the various agencies responsible for groundwater information and water quality to share information and jointly develop a database of the present status of our groundwater and its quality. This will require extensive cooperation and sharing of information between the various agencies and a long-term commitment from government to support the pooling of information.

7) Encourage the testing of groundwater supplies on an annual or biannual basis by providing water analysis at a reduced cost. This information can then be used in the development of the overall groundwater availability/water quality database and will assist in the determination of where and when further monitoring is required.

8) Initiate a regular monitoring program of the various aquifers for possible contaminants such as pesticides to identify areas of concern. Once these areas of concern are identified, long-term monitoring and possible corrective actions can be implemented. Without good water quality information indicating our present situation it will be very difficult, if not impossible, to determine what is happening to our resources in the future.

8 Conclusions and Recommendations

Water is one of the most important resources in the Upper Assiniboine River Basin. Water is used for domestic use, economic development, agricultural purposes, livestock watering, fishing and recreation.

In general, any substance that may enter a water body can be a potential source of pollution. The type of pollutant and the volume which is introduced to the water supply are the primary factors that influence water quality. The resulting water quality depends on the original quality of the receiving water, its assimilative capacity, level of mixing, rate of water flows, and the rate of chemical and biological changes. Effluents from sewage treatment facilities, suspended sediments, and nutrients and pesticides in runoff from agriculture and livestock operations are the major sources of pollutants.

8.1 Groundwater Monitoring

Groundwater is often the sole water source for municipal, domestic, agricultural and industrial needs. Groundwater can be contaminated from a number of sources, including fertilizer and pesticide applications, manure storage and spreading, livestock operations, effluent irrigation, landfills, leaking septic and fuel storage tanks and lagoon seepage.

Once an aquifer is contaminated, it is difficult, expensive and time consuming to clean up. Because a contaminant cannot be easily removed from groundwater supplies, prevention is the only effective approach to maintain a safe and clean supply.

The long-term potential for groundwater quality in the Upper Assiniboine River Basin may degrade from its current level as a result of human activity. Predictions concerning such degradation are difficult given the large number of unknowns present. It is certain, however, that the future of our groundwater quality is not only the responsibility of governments and concerned agencies, but also of every person living in the Basin.

Recommendation 1.

Aquifers should be monitored regularly for possible contaminants.

Once these areas of concern are identified corrective actions can be implemented. Without good water quality information indicating our present situation it will be very difficult, if not impossible, to determine water quality trends.

Recommendation 2.

Aquifer maps should be developed to define various aquifers in the region with an emphasis on unconfined or vulnerable aquifers.

Aquifer maps would be utilized by local governments and planners as a guide in the future development of the area.

Recommendation 3.

Testing of private groundwater wells should be encouraged on an annual or biannual basis through water quality testing services at a reduced cost.

This information can also be used to develop an overall groundwater availability/water quality database and assist in determining future monitoring needs.

Recommendation 4.

Groundwater monitoring should be done in the vicinity of hazardous storage facilities (e.g., chemical collection depots, landfills, discontinued bulk fuel depots, and gas stations) to determine whether contamination is occurring.

8.2 Surface Water Monitoring

Nutrients entering surface and groundwater supplies from external sources such as agricultural fertilizer can impact water quality, creating negative consequences for wildlife, livestock, human and aquatic biota. Nutrient loading of surface water may result in algal growth. This may cause reductions or changes in aquatic biota due to the shading effect of algae in the water column or lowering of dissolved oxygen levels that result during decomposition of algae. Species of algae may develop which are highly toxic to humans, livestock and wildlife. Algae may negatively impact drinking water quality by imparting odour and taste.

Recommendation 5.

Long-term monitoring of surface water quality and riparian health on a watershed basis should be implemented. Monitoring should be carried out to collect information to confirm the current status of water quality and identify potential problems in the Basin.

This should utilize well defined constituents and protocols along with efficient implementation to establish baseline information, analyze emerging trends or issues, and plan/develop practical, targeted solutions and recommendations.

Recommendation 6.

Monitoring should continue on the Assiniboine River at the PPWB station near Kamsack at a frequency that is capable of detecting long-term trends in water quality.

The levels of dissolved oxygen, total phosphorous and dissolved manganese already exceed the Prairie Provinces Water Board (PPWB) Water Quality Objective for the Assiniboine River and could potentially have a detrimental effect on downstream users in the Basin.

8.3 Agricultural Practices

Agriculture and livestock production are dominant activities in the Basin. Surface runoff may reduce water quality of the receiving water body. Some of the impacts of agricultural land runoff on water quality include nutrient loading, pesticide and heavy metal contamination, erosion and sedimentation, and removal of the natural buffering capabilities of wetlands through their drainage.

Management practices associated with all types of livestock activities will have an impact on groundwater and surface water quality. Impaired water quality can result from soil erosion due to overgrazing of pasture; nutrient overloading of streams, water bodies and groundwater through improperly controlled runoff from livestock pens or improper application of manure; and, degradation of shorelines due to overstocking of cattle near streams, lakes and sloughs. With the increase in both the number and size of livestock operations within the Basin, sustainable livestock management practices become more critical.

Agricultural land drainage including the removal of wetlands may cause impacts to surface and groundwater. Wetlands significantly reduce phosphorous, nitrogen, BOD and coliforms. Removal of wetlands reduces this function. Agricultural land drainage may aggravate soil erosion resulting in increased sedimentation in the receiving water body. Increased silt loading and turbidity can present problems for recreation use of water bodies because of decreased visibility. Sediments are also known to cover fish spawning areas and can also affect the storage capacity and life span of reservoirs.

High concentrations of ammonia nitrogen may occur in water sources as a result of fertilizer runoff facilitated by drainage. Increased concentrations of ammonia nitrogen in surface water can stimulate the growth of algae and aquatic plants. Ammonia readily converts to nitrate and nitrite through a chemical reaction which uses dissolved oxygen. Reduction of dissolved oxygen can negatively impact aquatic biota. High levels of nitrogen in groundwater may also create a health problem called blue-baby syndrome in infants, which can lead to respiratory failure. High levels of nitrogen in water supplied to livestock can result in weight loss and poor feed conversion.

Phosphorous laden soil particles may be added to a water body by erosional surface runoff facilitated by drainage. Phosphorous adhereing to soil particles can be released into the water column. In its dissolved form, phosphorous is readily taken up by plants and algae. Phosphorus is often a greater concern for aquatic systems than nitrogen because it is generally considered the limiting factor for the growth of freshwater phytoplankton such as algae.

Pesticides may contaminate surface and groundwater. Drainage of lands on which these chemicals are used may facilitate their movement to water bodies. Pesticides can be toxic to humans, livestock and wildlife depending on a number of factors including the type of pesticide and dilution rate.

Recommendation 7.

Best Management Practices for agriculture and other industries in the Basin should be developed and promoted with emphasis on surface and groundwater protection. A glossary of terms for seeding, tillage and rotational systems should be developed that is consistent with the agricultural industry.

Best management practices have been advocated as a means to reduce non-point contamination of water resources from agriculture. Such practices include avoiding chemical contamination by maintaining a suitable distance from wells during application, practising proper chemical storage, managing fertilizer applications to reduce nitrate leaching, and minimizing surface runoff.

Recommendation 8.

The livestock industry should be encouraged to improve riparian areas through alternative pasturing, livestock watering systems, and properly located and managed winter feeding sites.

Recommendation 9.

Information should be provided on the value of manure as a nutrient-rich fertilizer.

Manure is a nutrient-rich fertilizer product very suitable for application to crop lands. As with any fertilizer product, the manure should be applied to the land to match the nutrient requirements of the crop being grown. Over-application of the manure not only compromises the environment through a potential increase in runoff and leaching, but also can result in economic loss to the farmer by extending crop maturation time.

Recommendation 10.

Water quality should be taken into consideration when evaluating drainage projects. Criteria should be established for rating or evaluating drainage projects. A code of practise should be developed for construction of drainage projects to reduce impacts on water quality.

The evaluation process would include such items as soil texture, slope, seeding system, extent of residue cover, significant rainfall and runoff events, average annual precipitation and impact on wetlands.

Recommendation 11.

Watershed-based planning should be undertaken to account for the cumulative impacts of drainage on water quality. Maintenance of existing wetlands should be encouraged to ensure some surface water storage within the Basin.

Recommendation 12.

Maintenance of natural vegetation cover around water bodies should be encouraged. Licensing preference should be given to drainage works that include establishment of vegetation cover such as grasses to protect the ditch from erosion. Buffer strips or bush adjacent to water courses or water bodies should be protected to reduce the potential for erosion or contamination of the receiving water body.

Recommendation 13.

Pesticide container disposal sites should continue to be used along with proper on-farm preparation of the containers for disposal (e.g., triple rinse puncture containers).

Recommendation 14.

Education activities should be implemented to caution pesticide users to avoid cleaning sprayers and chemical containers near open water and to apply product at the proper rates and follow label restrictions and recommended practices.

8.4 Effluent Management

Effective wastewater treatment involves proper planning, design, construction, operation, monitoring, and an investment of hundreds of thousands of dollars by each community. Treatment is provided by lagoons or mechanical wastewater treatment plants.

The approach to effluent treatment employed by the Town of Roblin shows that many towns may be able to use their effluent for economic activity, while reducing the impact on water bodies from lagoon discharges. This will protect the rivers and lakes and provide continued enjoyment by residents and tourists, while ensuring that water quality is maintained.

Recommendation 15.

More extensive studies and monitoring are required to determine any long-term effects of lagoons on receiving water bodies.

At present there is no evidence to suggest that wastewater release or seepage is a major concern in the Basin, but it may be a contributing factor to water quality deterioration.

Recommendation 16.

The required quality of wastewater effluent and the procedures for its release to the Assiniboine River should be reviewed.

A reduction of nutrients in the Assiniboine River may have the potential to reduce accelerated aquatic weed growth in the river. The release of effluent should be coordinated with stream flows to dilute nutrient levels.

8.5 Groundwater Protection

One of the greatest threats to the integrity of groundwater, regardless of whether it is from a confined or unconfined aquifer, is the well itself. The chances of contamination around or through the existing well can be easily prevented. Many wells become contaminated due to owner error or lack of knowledge.

Even more of a concern, is the number of old and abandoned wells. Given that wells have an average life of 15 to 30 years, many wells have been drilled and subsequently replaced over the years. Wells can provide a direct connection for easy introduction of contaminants from the surface to an aquifer. Groundwater protection recognizes that prevention is the only effective approach to deal with the potential for groundwater contamination.

Recommendation 17.

Abandoned wells should be properly decommissioned.

Recommendation 18.

Wells should be properly sited, constructed, and maintained to protect groundwater from contamination.

Recommendation 19.

A public education program on proper well and aquifer management should be initiated to protect our groundwater formations from contamination.

Recommendation 20.

More stringent regulations should be applied to the construction and monitoring of new facilities such as landfills, lagoons, chemical storage and pesticide container disposal sites.

8.6 Information and Education

Recommendation 21.

Agencies responsible for surface and groundwater management and protection should be encouraged to share information and develop a joint database of the current status of water quality.

Recommendation 22.

Agencies should provide coordinated and effective communication to the public and stakeholders on issues related to landscape management that affect surface and groundwater.

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Glossary

Conservation Tillage - any tillage sequence in which the object is to minimize or reduce loss of soil and water. Operationally, it is any tillage and seeding sequence which leaves more than 30% of crop residue on the soil surface.

Conventional Tillage - primary and secondary tillage operations normally performed in preparing a seedbed and/or cultivating for a given crop grown in a given geographical area; usually results in less than 30% of crop residues remaining on the surface of the soil after completion of the tillage sequence.

Cultivated Land - For the purposes of this report, cultivated land is land that is tilled and used for annual cropping.

Drainage - Movement of water off of land. Drainage may be natural or man-made. For the purpose of this report, drainage refers to movement of surface water by man-made works.

Ecosystem - "a community of organisms interacting with one another and with the chemical and physical factors making up their environment." The chemical and physical factors include sunlight, rainfall, soil nutrients, climate, salinity, etc. An ecosystem is inherently leaky: that is, at a minimum, energy and nutrients move in and out. Just as likely, individual organisms (such as seeds, spiders, and sparrows) move in and out as well.
Some considerations based on this definition are:

- All parts of the planet, from a microbe drifting in the upper atmosphere, to the wheat midge egg in the soil and the tadpole in the slough, are within an ecosystem. An ecosystem has no defined size.
- Ecosystems are not necessarily stable, nor are all their component species necessarily native to the area. Purple loosestrife is an example on an intruder that now can be a member of a given ecosystem.
- Ecosystems are difficult to separate from each other. Boundaries may be drawn to study a specific species, but the boundary is arbitrary.
- Based on the definition now used by ecologists, an ecosystem can be large or small and can include both pristine and highly developed areas.

Holding Pond - associated with the collection of runoff from outdoor livestock pens, primarily those of cattle. Holding ponds are usually less than 1.2 metres deep. A holding pond confines runoff water which has been exposed to manure and livestock. The holding pond is rarely at design capacity since it is dependant on precipitation events, the spring melt, and evaporation. Very few solids accumulate in a holding pond. Most of the solids normally remain within the manure pack in the pens until field spread or are stockpiled for future field spreading. If a high concentration of solids is anticipated in the runoff, a settling basin is used before the holding pond.

Intensive Livestock Operation (ILO) - means the confining of any of the following animals, where the space per animal unit is less than 370 m^2: poultry, hogs, sheep, goats, cattle, horses, elk, mule deer, white-tail deer, fallow deer, bison, or any other prescribed animals. The number of animals of each species required to make one animal unit is shown in Table 1 of The *Agricultural Operations Act* or Appendix B of the *Guidelines for Establishing and Managing Livestock Operations*. Approval is required for any intensive livestock operation that:

- contains an earthen manure storage area or lagoon;
- involves the rearing, confining, or feeding of 300 or more animal units; or
- confines more than 20 animal units, but less than 300 animal units for more than 10 days in any 30-day period, within 300 metres of surface water or 30 metres of a domestic water well not controlled by the operator.

No-Till or Zero Till - a procedure whereby a crop is planted directly into the soil with no primary or secondary tillage since the harvest of the last crop; usually a special seeding machine is required to prepare a narrow, shallow seedbed immediately around the seed.

Manure Storage - there may be some confusion in the terminology of manure containment practices. An earthen manure storage (EMS) is the term associated with the storage of liquid manure in an earthen structure. An EMS is strictly a storage unit and is not designed for "treatment" of the waste as is expected of municipal lagoons. As a rule, an EMS is 3 to 5 metres deep. Within the Basin, EMSs are used primarily for the storage of liquid hog manure. There is limited use of EMSs for storage of liquid dairy and poultry manure. Manitoba suggests that an EMS should have a minimum 200 days of storage; Saskatchewan requests 400 days of storage for all new EMS structures. Both provinces require the involvement of professional engineers in the design of an EMS.

Minimum Tillage - the minimum use of primary and/or secondary tillage necessary for meeting crop production requirements under the existing soil and climatic conditions, usually resulting in fewer tillage operations than normally used in conventional tillage.

Pesticide - is defined as any chemical used to control pests such as weeds (herbicides), insects (insecticides), crop diseases (fungicides), and rodents (rodenticides). In general, insecticides are more toxic than herbicides. Organophosphorous insecticides are more toxic than carbamates and organochlorine insecticides.

Riparian Area - the transition zones between land and water environments. They are the narrow strips of land located along streams, lakes, potholes, springs, coulees, and wooded draws - anywhere that water is plentiful. Riparian area boundaries can normally be identified from the surrounding uplands by an increased abundance of water and by plant communities that are different from those of the drier uplands.

Reduced Tillage - a tillage system in which the total number of tillage operations used for seedbed preparation is reduced from that normally used on that particular field or soil.

Stockpiling of Manure - The piling of manure prior to spreading on fields is considered an acceptable practice provided the location of the pile(s) ensures protection of ground and surface water.

Waste Storage Plan - describes the type of storage, duration of storage, capacity, drawings showing dimensions, setback distances, groundwater conditions, construction techniques, freeboard, description of soils investigation, and details of monitoring programs.

Waste Management Plan - outlines the method of handling, utilizing, and disposing of waste by-products originating from the intensive livestock operation.

Watershed - the "Entire region drained by a waterway that drains into a lake or reservoir; total area above a given point on a stream that contributes to the flow at that point (the definition used for defining the UARB Study boundary); the topographic dividing line from which surface streams flow in two different directions." Except where two watersheds are separated by very flat areas, it is relatively easy to define watershed boundaries. A watershed can be any size ranging from the smallest of streams to everything upstream of a river's discharge point at the ocean shore.

Appendix I

Terms of Reference

Terms of Reference

(revised May 16, 1997)

Based on the issues identified and prioritized with the assistance of a series of public meetings and input from water management professionals, and with some input from the Management Committee with respect to the availability of funding, a work plan was developed to address the water quality issues of the Upper Assiniboine River Basin.

1.1 Effects of Drainage on Water Quality

Activities:

- Carry out a literature review of the effects of agricultural drainage on water and relevance to the Upper Assiniboine River Basin.
- Develop a public information program based on the literature review (may require the development of a new brochure).
- Develop a detailed map for the public, showing the extent of the drainage within the Basin.

1.2 Nutrient Enrichment - Livestock Access to Watercourses

Activities:

- Carry out a literature review of the effects of livestock watering and range management practices on water quality and relevance to the Upper Assiniboine River Basin.
- Develop a public information program based on the literature review, and compile relevant existing public brochures.
- Look for an appropriate site for demonstrating appropriate livestock watering strategies.
- Examine opportunities for funding of a demonstration site.

1.3 Nutrient Enrichment - Effluent Discharge

Activities:

- Assemble information on existing municipal systems (e.g., number and location of systems, frequency and volume of discharge, last five years of effluent quality data).
- Conduct a literature review of impacts of municipal lagoon releases.
- If none are available, develop brochures on how lagoons are operated and their environmental effects.

1.4 Trends in Water Quality Data

- Analyze the historical water quality data from the Prairie Provinces Water Board site at Kamsack and any other water quality sampling stations where the data will permit analysis of trends.

1.5 Groundwater Protection

- Compile existing education and awareness materials regarding the need to protect groundwater from contamination.
- If necessary, develop and print a new public brochure on groundwater protection strategies.

1.6 Inventory

- Compile list of livestock operators, size and location.
- Compile a list of lagoons, size and location.
- Compile a list of landfills and pesticide container storage facilities.
- Map all of the above.

1.7 Public Information Program

- Relay all of the information developed above to the public to encourage their participation in addressing water management issues in the Basin.
- Assemble existing relevant brochures.
- Develop and print new brochures as required with the assistance of the Communications Committee.
- Organize and deliver seminars on water quality to Basin residents (possibly to be delivered by experts in appropriate fields).

Appendix II

Upper Assiniboine River Basin Water Quality Study
Final Report, November 1998

Literature review prepared for:
The Upper Assiniboine River Basin Water Quality Study
Water Quality Technical Committee

Dillon Consulting Limited
Winnipeg, MB
97-4531-01-01, 136 p.

Upper Assiniboine River Basin Water Quality Study

Final Report

November 1998

Upper Assiniboine River Basin - Water Quality Study

Water Quality Technical Committee,
Upper Assiniboine River Basin Study

97-4531-01-01

Submitted by

Dillon Consulting Limited

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Our File: 97-4531

November 18, 1998

Upper Assiniboine River Basin Study
Technical Committee Water Quality
c/o Sask Water
#300 - 3130 8th Street E.
Saskatoon, Saskatchewan S7K 2H6

Attention: Joanne Sketchell
Chair, Technical Committee on Water Quality

Upper Assiniboine Water Quality Report

Dear Ms. Sketchell:

As discussed with you, while a final report for this study was submitted on August 28, 1998, the attached report and computer diskette represents changes made to this report, based on further Committee review.

Changes are based on input from two reviewer's comments: a marked up report, and a typed list of comments. As agreed to with you, Dillon has made all changes that do not require additional research. The following comments from the list were therefore not addressed: numbers 2, 5, 7, 8, 9, 10, 18, and 21. In addition, the comments on page 38 of the marked up report may require some additional information. As we discussed, locations of figures have been clearly marked so that you can insert originals from PFRA. I have also assumed that you can reuse the original tables in the appendices.

We hope that these additional changes provide you with a quality of report that can be readily integrated into the larger Upper Assiniboine River Study. Once again, thank you for selecting Dillon for this interesting study.

Yours truly,

DILLON CONSULTING LIMITED

N. E. Barnes, P. Biol.
Project Manager

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EXECUTIVE SUMMARY

General

This report documents the findings of a literature review of sources and types of water quality impacts in the Upper Assiniboine River Basin. It is part of a larger-scale study to examine all aspects of the basin in order to develop a comprehensive management strategy. It involves numerous provincial and federal agencies from Saskatchewan, Manitoba, and Canada.

The scope of work for this project focusses on the following issues:

- Drainage and surface runoff within the context of cultivation.
- Rangeland and livestock activities and the corresponding implications for water.
- Municipal lagoons, septic tanks and contaminated sites, and their implications for water quality.
- Ground water quality in the basin and the available protection and management options.

Parameters of Concern

The research addresses the following parameters of concern:

- Nutrients (nitrogen and phosphorus)
- Dissolved Oxygen
- Pesticides
- Heavy Metals
- Turbidity/Sedimentation
- Pathogens

Sources of nutrients in the basin are derived from activities such as fertilizer application and manure/sewage storage and application. These tend to elevate levels of nitrogen and phosphorus in surface and ground water. High levels of nitrogen in surface water can be toxic to fish, wildlife, and humans, and lower levels can cause rapid eutrophication of water bodies. Nitrogen can also leach to ground water supplies. While phosphorus typically does not leach to ground water, it is usually more influential in causing eutrophication of surface water bodies. Nutrients also indirectly lower oxygen levels in surface water, also affecting aquatic life.

Pesticides are often important in agriculture to control weeds, insects, and fungi. They can be directly toxic to wildlife and humans and tend to be very persistent, sometimes held in soil for several months, being released during high rainfall or flood events.

Heavy metals are typically a component of manure, municipal effluent, and landfills, and are components of some fungicides. They can be toxic to humans, fisheries, and wildlife, and several can bioaccumulate in the food chain.

Turbidity and sedimentation can occur when the vegetation cover is removed and land is exposed. Sediments can directly affect aquatic life by covering fish spawning beds, reducing light penetration for plants, and can also serve to carry contaminants to water sources. As expected, the concern is typically higher in the spring months, or during high precipitation events. While reservoirs tend to trap sediments and alleviate downstream concerns, sediments can reduce the efficiency of their operation over time.

Pathogens are associated with human/animal waste materials, such as manure spreading and municipal lagoons. They carry obvious concerns with disease and health of organisms.

Cropping

Cropping, field runoff, and drainage activities involve four main activities that are important for agriculture from a water quality perspective: application of fertilizer, pesticide application, cultivation, and drainage.

Fertilizer application has the potential to introduce nutrients to surface and ground water. This typically occurs when application rates exceed crop uptake rates. Some research indicates that nutrient levels can be higher near areas where fertilizer is used, but high nutrient levels are not attributed solely to this activity. While phosphorus levels in the basin still often exceed water quality criteria, the decreases in nitrogen levels since 1980 has been attributed to improvements in municipal water treatment technology.

As indicated previously, pesticides are often important in agriculture, to protect from weeds, insects, and fungi. There are guidelines on use, but problems can still occur. Pesticides do not appear to be as big a concern in the prairies as in the United States or in eastern Canada. They have been detected in the prairies, but are generally below acceptable water quality criteria. Some areas of the basin are more susceptible to problems, due to local conditions such as soil type, slope, climate, and depth to ground water.

Tillage methods are used to control weeds, and are thought to increase soil productivity. Potential concern relates to increased erosion and contaminant loading to water. This potential is influenced by aspects such as timing, soil type, and slope. Conservation tillage is a method to minimize erosion. However, more herbicides are typically used over conventional methods and this can increase risks of water contamination.

Drainage involves grading, and/or construction of ditches, to allow more land to be brought into agricultural production. Potential effects include erosion, contaminant transfer, and loss of wildlife habitat. Efforts are being made to maintain wetlands and wooded areas on agricultural lands, in order to maintain wildlife habitat and reduce flood problems.

Irrigation is not used extensively in the basin. Concerns include an increase in soil salinity, erosion, and contaminant transfer to water. Aspects such as timing and soil type influence the potential for impacts.

Livestock and Range Management

Several livestock and range management activities, relating to cattle, hog, and poultry, are expanding in the basin. Several have presented recent challenges to regulate.

Livestock watering presents the potential for erosion at watering sites and the introduction of contaminants such as nutrients and pathogens associated with manure. These issues are also a concern for range management. In addition, forage crops are sometimes fertilized, which has impacts previously discussed. Good management techniques, such as careful monitoring and rotating the use of grazing sites and watering areas, can minimize this concern.

Feedlots and manure management involve more intensive livestock operations. Waste materials typically accumulate in pens, or are held in earthen manure storages and/or applied to land. Problems with increased nutrients, pathogens, and heavy metals have the potential to occur, to both surface and ground water. The degree of impact is related to animal density, frequency of manure removal, treatment method, soil types, and climate.

Municipal Lagoons, Septic Systems, and Contaminated Sites

Larger communities typically require lagoons to treat effluent; smaller communities in remote areas can use septic systems, in an effort to reduce contaminant levels to acceptable levels. Landfills, industrial sites, and chemical storage facilities have the potential to be contaminated sites.

While guidelines have been developed for the design and operation of these facilities, the potential exists for surface and ground water to be contaminated with pathogens, nutrients, heavy metals, and pesticides. The susceptibility is related to aspects such as location, soil type, and timing of application/release.

There have been documented cases of point-source contamination from lagoons, septic systems, and contaminated sites in the basin.

Ground Water Protection

Government agencies in both Saskatchewan and Manitoba have been given the responsibility to protect ground water, and to that end, they regulate many activities and/or sources of ground water contamination.

Methods of management include education, monitoring, regulation, and enforcement. Best Management Practices are developed for agricultural activities and licences are required to site, design, and operate lagoons, landfills, etc. Methods of well decommissioning have also been developed.

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1.0 INTRODUCTION

1.1 Purpose of Study

A review of the Upper Assiniboine River Basin is being undertaken as a cooperative effort by the Governments of Manitoba, Saskatchewan, and Canada. Various agencies, including Environment Canada, Prairie Farm Rehabilitation Administration (PFRA), Sask Water, Saskatchewan Environment and Resource Management, Saskatchewan Agriculture and Food, Manitoba Natural Resources, Manitoba Environment, Manitoba Agriculture, and the Manitoba Water Services Board of Manitoba Rural Development, are involved in this study to assess the basin's water resources and the impact of development activities. This review is the most comprehensive review undertaken to date of the Upper Assiniboine Basin and will form the basis for future management decisions affecting the basin.

As part of the overall basin review, Dillon Consulting Limited was contracted by the Upper Assiniboine River Basin Water Quality Technical Committee to conduct a water quality study. The specific objectives of the study were to conduct a literature review of the effects of agricultural drainage, livestock watering, range management, and municipal lagoon releases to ground and surface water quality relevant to the Upper Assiniboine River Basin (Figure 1). In addition, ground water protection information and related education materials were to be compiled.

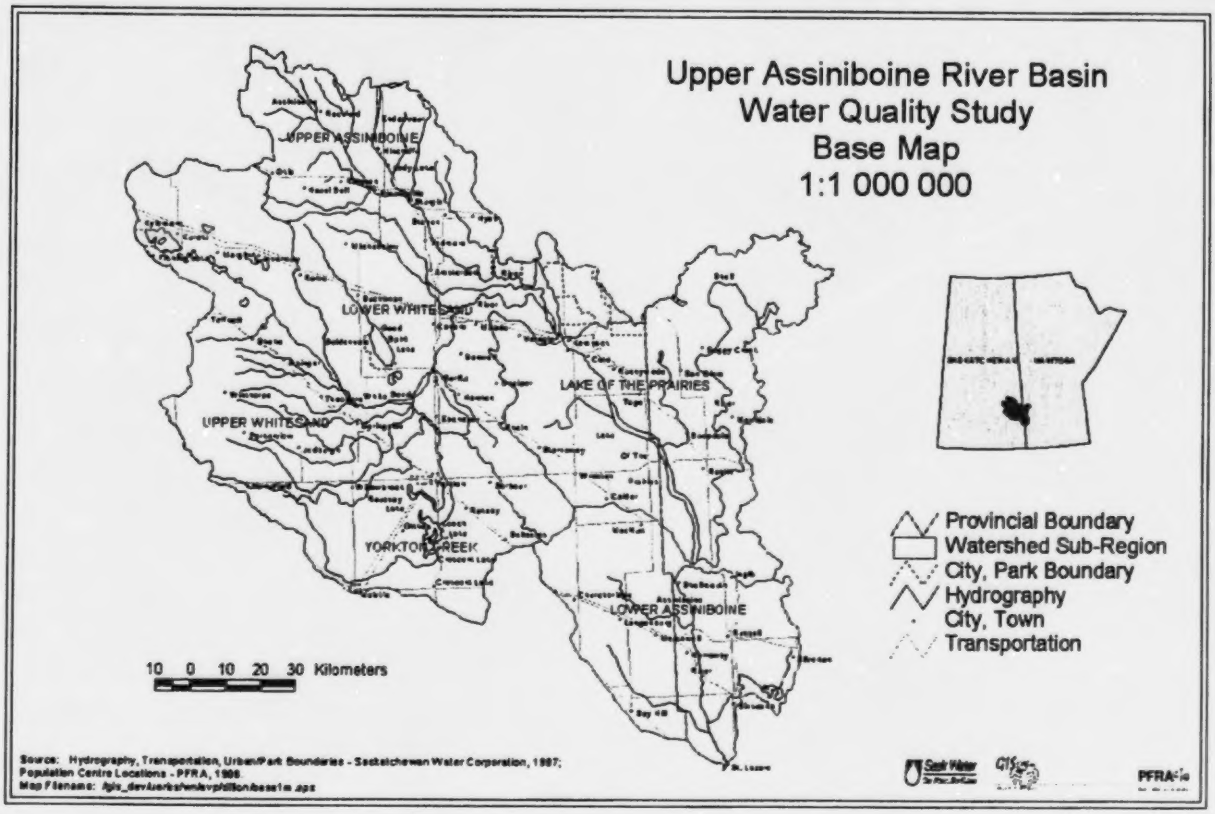
1.2 Scope of Study

This report documents the results of water quality research associated with the following issues:

- Drainage and surface runoff within the context of cultivation.
- Rangeland and livestock activities and the corresponding implications for water.
- Municipal lagoons, septic tanks and contaminated sites, and their implications for water quality.
- Ground water quality in the basin and the available protection and management options.

This water quality study is limited to a review of existing literature and information on the current state of ground and surface waters in the basin. The research is based primarily on information that is directly related to the Upper Assiniboine Basin. However, where such information was not available, studies generic to the Canadian Prairies or other specific regions were reviewed.

Figure 1 Upper Assiniboine River Basin


Upper Assiniboine River Basin
Water Quality Study
Base Map
1:1 000 000
UPPER ASSINIBOINE
LOWER WHITESAND
UPPER WHITESAND
YORKTON CREEK
LAKE OF THE PRAIRIES
LOWER ASSINIBOINE
SASKATCHEWAN
MANITOBA
Provincial Boundary
Watershed Sub-Region
City, Park Boundary
Hydrography
City, Town
Transportation
10 0 10 20 30 Kilometers
Sask Water
PFRA

Source: Hydrography, Transportation, Urban/Park Boundaries - Saskatchewan Water Corporation, 1997;
Population Centre Locations - PFRA, 1998.
Map Filename: /gis_dev/users/sm/avp/dillon/base1m.aps

In some instances, where specific research has not been conducted in Canada, the Environmental Protection Agency and other U.S. government studies were consulted.

Based on available literature and information at the time of this report, the current state of the basin was characterized in terms of water quality and land use activities. In addition, where possible, past trends as well as anticipated changes in land use activities were reviewed for the purpose of identifying future water quality conditions in the Upper Assiniboine River.

There are several other activities with implications for surface and ground water quality that were not examined as part of this study. These include the following:

- Highway deicing salt, which has caused ground water problems in the northeastern United States.
- Leaking sewer lines, which may release organics, bacteria and nitrates into the ground water.
- Detailed analyses of point sources such as accidental chemical and hydrocarbon discharges.
- Urban storm-water runoff.
- Stream crossings by roads, pipelines, transmission lines, and railway lines.
- Industrial activities such potash and forestry.
- Dams, small impoundments, and dugouts.
- Hydrocarbon contamination from underground and surface storage tanks and pipelines and municipal landfills

Discussions of water quality in the report are based on the availability of existing data and trend analysis. Due to limitations of the study, in-depth analysis of existing data and trend calculations were not possible.

Both provincial and federal guidelines have been developed that establish criteria for acceptable levels of water quality parameters. Guidelines may vary in their applicability depending on the nature of specific locations, timing and regularity of quality changes, technical ability to measure various parameters, and perceptions of risk (Harker, 1997). For the purposes of this study, it has been assumed that national and provincial water quality guidelines are appropriate for this basin.

1.3 Characteristics of the Basin

1.3.1 General

The Upper Assiniboine River Basin is primarily occupied by agriculture producers and small communities (Figure 1). Some of the communities in the basin have experienced an increase in population, with people drawn to larger centres from rural areas. In general, rural populations have dropped considerably since 1974, which is consistent with rural population trends elsewhere in the Western Canadian Prairies. Businesses in the region are often associated with the agricultural sector or otherwise provide services to local communities. Mixed grain, forage, and small livestock operations are the dominant farming activities. Other agro-business activities found in the area are meat packing facilities, dairies, bakeries, and feed mills (Sask Water, 1995).

The following section provides a brief overview of the biophysical characteristics of the Upper Assiniboine River Basin that have implications for water quality issues.

1.3.2 Climate

Climatic conditions strongly influence the hydrology of the entire basin. The Interior Plains climate is classified as semi-arid, having comparatively low annual precipitation and high evaporation and transpiration rates in the summer months. The upper basin drains an area where annual precipitation rates are approximately 400 mm and annual runoff rates are slightly above 50 mm on average. However, precipitation has been known to vary greatly from year to year and long-term climate cycles of high and low precipitation has been noted (Canada West Foundation, 1982). Such fluctuations can lead to dramatically variable river and stream flows, which can have implications for water quality. However, the precipitation in the Assiniboine and Shell River watersheds is sufficient to maintain soil moisture at a level to support agriculture. Due to sufficient moisture present in most years, irrigation is not required for most grain, cereal, and forage crops grown in the upper Assiniboine basin.

1.3.3 Topography and Drainage

This region is characterised by a series of steppes that gently slope from the southwest to the northeast. The Assiniboine Basin straddles the lower two steppes, rising in Saskatchewan and flowing east to the Manitoba Escarpment and down into the Manitoba Plain (Canada West Foundation, 1982).

The Upper Assiniboine River Basin occupies a total of 19 300 km^2 (Ashmore, 1990). Three major river systems drain the basin: the Assiniboine and the Whitesand rivers in Saskatchewan, as well as the Shell River that flows from the Duck Mountains in Manitoba. Each of these is fed by numerous streams, marshes and ground water outlets. The Assiniboine and Whitesand rivers converge just north west of Kamsack and flow into the Lake of the Prairies Reservoir at the Manitoba - Saskatchewan border. The Shell River flows into the Lake of the Prairies at the Shellmouth Dam site (Figure 1).

The Upper Assiniboine River Basin is an interjurisdictional basin covered by the Prairie Provinces Water Board's Master Agreement on Apportionment. This agreement guarantees that 50 percent of natural flow from Saskatchewan reaches Manitoba and that minimum water quality objectives are met for rivers such as the Assiniboine which flow over the boundary from Saskatchewan to Manitoba (PPWB, 1992).

The Assiniboine River Basin natural flows vary between almost nil and 120 cubic metres per second (m^3/s), with a mean of 9.3 m^3/s (PFRA, 1980). Flow rates fluctuate considerably throughout the year, with the majority of flow ranging from 30 to 40 percent of the total annual flow, occurring during the April melt period (Canada West Foundation, 1982). Frozen soil conditions favour surface runoff of meltwaters from accumulated winter snow and any new precipitation during the spring months. In contrast, the summer and fall rains are more likely to be absorbed, replacing soil moisture and ground water losses, leaving minimal runoff for rivers and streams. The gentle slope of the prairie plain also contributes to this high rate of absorption in the summer and fall.

Surface and ground water quality is variable across the basin, being affected by various local geographic as well as manmade and natural environmental conditions. Since this is an interjurisdictional basin, water quality parameters are not only measured by Environment Canada, Sask Water, and Manitoba Environment within their various jurisdictions, but also by the Prairie Provinces Water Board (PPWB, 1992) which monitors quality and flow at the provincial boundary. The PPWB plays a coordinating role, which is funded and operated by contributions from Manitoba, Saskatchewan, Alberta, and Canada.

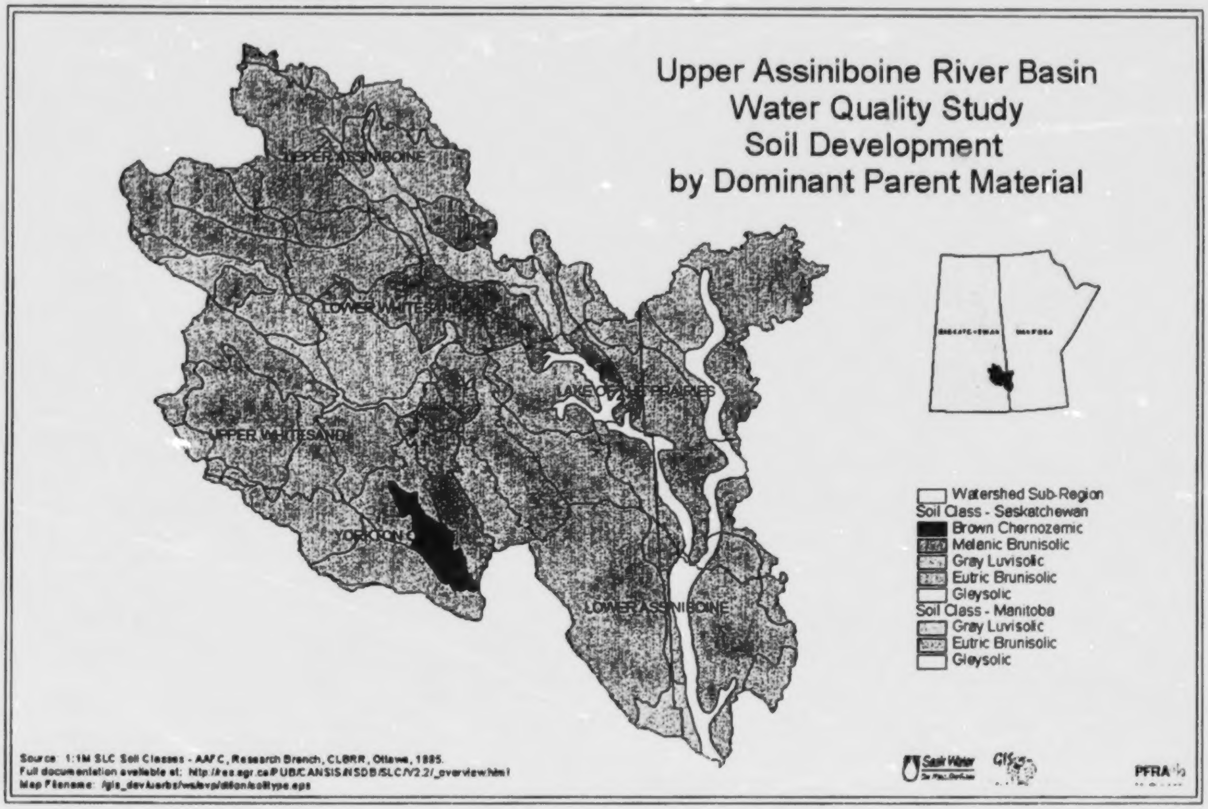
1.3.4 Soils, Surficial Geology, and Hydrogeology

The Assiniboine River Basin occupies a geographic area commonly known as the Interior Plains. The region, underlain by Cretaceous shale, is covered by an undulating, kettled, organically rich glacial till. The general physiography of the study area is dominated by glacial meltwater features formed during the last glacial period. Figures 2 and 3 display soil development and texture for the basin. The dominant soil type is eutric brunisolic (a loamy soil) and melanic brunisolic (a silt loam), as well as gray luvisolic (loamy fine sand) soils that were deposited in the upland area of the Basin. As shown in Figure 2, gleysolic soils occur mainly in the river valleys and are highly fertile because of alluvial deposits during periodic floods.

Since these are easily eroded soils and the topography is gently sloping, the creeks and rivers of the watershed are characterised by high sediment loads and meandering channels.

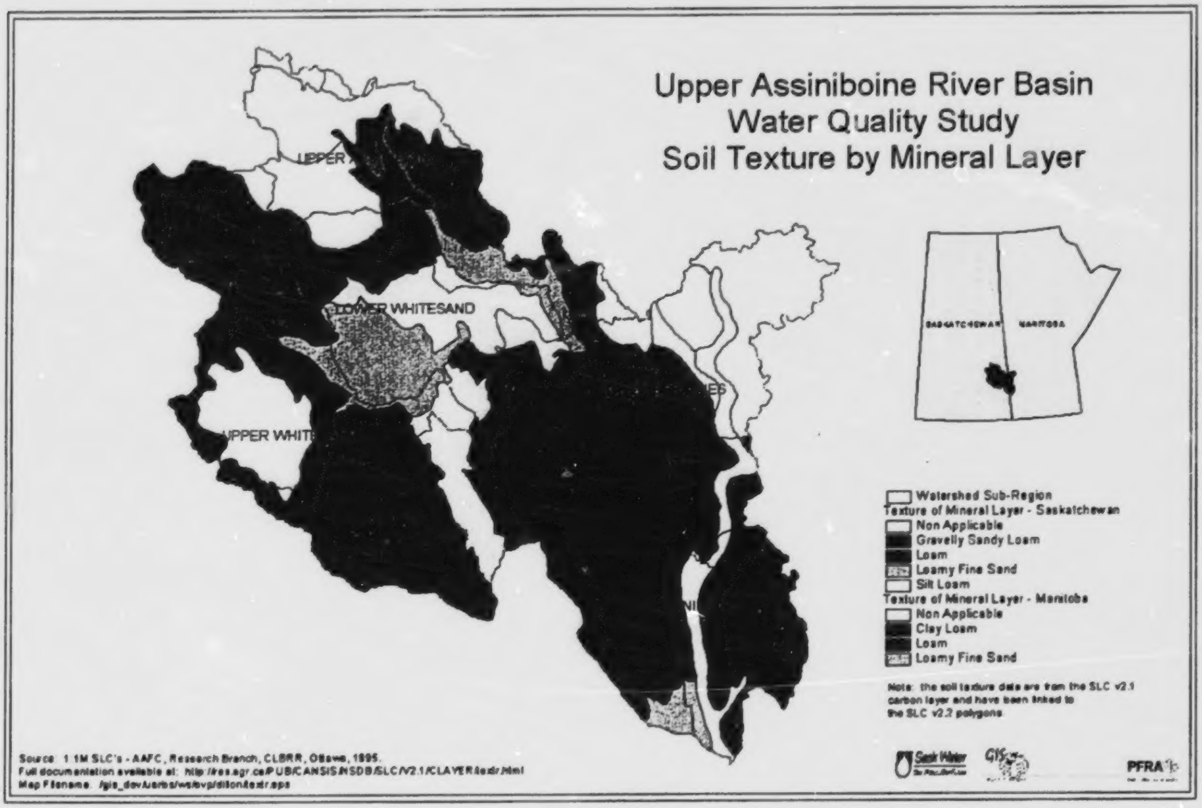
Ground water in the basin is heavily relied upon as a source of domestic and municipal water supply (Hess, 1981). The occurrence of ground water is typically described in terms of aquifers and aquitards. Aquifers are saturated permeable geologic units that can transmit significant quantities of water under ordinary hydraulic conditions. Usually, these are significant enough to yield well water for domestic, municipal or agricultural uses. Aquifers may or may not be homogeneous units in terms of water quality. Aquitards are less permeable geologic beds that transmit measurable ground water flow, but not in sufficient quantities to allow production wells (Freeze and Cherry, 1979). An aquifer system or formation consists of hydrologically interconnected aquifers and aquitards that form an identifiable unit between ground water recharge and discharge areas (Woodbury and Render, 1993).

Figure 2 Soil Development by Dominant Parent Material


Upper Assiniboine River Basin
Water Quality Study
Soil Development
by Dominant Parent Material
UPPER ASSINIBOINE
LOWER WHITESAND
UPPER WHITESAND
YORKTON
LAKE OF THE PRAIRIES
LOWER ASSINIBOINE
SASKATCHEWAN
MANITOBA
Watershed Sub-Region
Soil Class - Saskatchewan
Brown Chernozemic
Melanic Brunisolic
Gray Luvisolic
Eutric Brunisolic
Gleysolic
Soil Class - Manitoba
Gray Luvisolic
Eutric Brunisolic
Gleysolic
Sask Water
PFRA

Source: 1:1M SLC Soil Classes - AAFC, Research Branch, CLBRR, Ottawa, 1995.
Full documentation available at: http://res.agr.ca/PUB/CANSIS/NSDB/SLC/V2.2/_overview.html
Map Filename: /gis_dev/uerbs/wslevp/dillon/soiltype.eps

Figure 3 Soil Texture by Mineral Layer


Upper Assiniboine River Basin
Water Quality Study
Soil Texture by Mineral Layer
UPPER A
LOWER WHITESAND
UPPER WHITE
ES
NI
SASKATCHEWAN
MANITOBA
Watershed Sub-Region
Texture of Mineral Layer - Saskatchewan
Non Applicable
Gravelly Sandy Loam
Loam
Loamy Fine Sand
Silt Loam
Texture of Mineral Layer - Manitoba
Non Applicable
Clay Loam
Loam
Loamy Fine Sand
Sask Water
GIS
PFRA

Note: the soil texture data are from the SLC v2.1 carbon layer and have been linked to the SLC v2.2 polygons

Source: 1:1M SLC's - AAFC, Research Branch, CLBRR, Ottawa, 1995.
Full documentation available at: http://res.agr.ca/PUB/CANSIS/NSDB/SLC/V2.1/CLAYER/textr.html
Map Filename: /gis_dev/users/ws/vp/dillon/textr.aps

In the Upper Assiniboine River Basin, ground water recharge occurs primarily during spring melt and early summer rains. Recharge rates vary, but generally surficial aquifers have the highest rate of recharge and are often the preferred source of domestic and farm water. Surficial aquifers are shallow sand and gravel aquifers, 10 to 30 m in depth below the surface and often provide good quality, medium yield wells. Bedrock aquifers in this watershed are composed of fractured shale and are usually overlain with glacial and postglacial till. Water quality is more varied and yields tend to be lower than surficial aquifers. Underground valleys, which are composed of sand and gravel between 0.4 and 16 km wide and 15 to 90 m in depth, are called buried valley aquifers. Blanket aquifers are similar to buried, but are more laterally extensive. Both are usually high yield providers of good quality water (Buchanan et al., 1996).

Water quality often varies within aquifers. Areas nearest recharge zones, where precipitation readily enters the subsurface generally have lower levels of dissolved solids than those near discharge zones, where water makes its way back to or near the surface. Typically, the longer water has been underground, the more opportunity it has had to dissolve minerals. Consequently, bedrock aquifers tend to have lower water quality than surficial and buried aquifers. Lower recharge rates and greater depth from the surface also create more opportunities to dissolve solids into the ground water.

Underlying most of the Manitoba portion of the Upper Assiniboine River Basin is a deep bedrock aquifer called the Swan River Formation (Rutulis, 1982). The Odanah Shale bedrock aquifer is also present in the study area and is overlain by unconsolidated glacial and postglacial deposits of varying thickness. A major buried sand aquifer is also found in the Manitoba portion of the study area that runs along the east side of Lake of the Prairies (Betcher, et al., 1995). The Swan River Formation is overlain by several hundred metres of Cretaceous shale that separates it from the Odanah shale and the overlying Quaternary sand and gravel aquifers. These shallow Quarternary aquifers are occasionally used as a source of well water in the basin. Ground water quality is generally good and is a major source of water for individual farms and some communities.

The Hatfield Valley Aquifer is a major buried valley aquifer extending across the Saskatchewan portion of the study area into Manitoba. The Wynyard-Melville Aquifer is a laterally extensive, continuous blanket aquifer that lies just north of the Hatfield Valley Aquifer in Saskatchewan. The Wynyard-Melville Aquifer is composed of between 6 and 9 m of sand and gravel within the Quaternary Empress Group and is overlain with 15 to 31 m of till. Two major bedrock aquifers have also been identified in Saskatchewan: the Wynyard Formation and the Bredenbury as well as a minor one in the Rocanville-Esterhazy area (Pupp, et al., 1991). These deep aquifers generally have marginal to very poor water quality.

Due to the heavy reliance on ground water and concern over future water supply, lesser aquifers have been identified in the Yorkton area. These include the Orcadia Aquifer to the north west of the city, the Collacot Aquifer to the west and the Logan Aquifer to the east. The Leech System is found to the south and the Willowbrook system to the far west (Maathuis, 1991). Other areas of the basin are not as well studied (Betcher pers. comm., 1997).

1.3.5 Vegetation and Terrestrial Wildlife

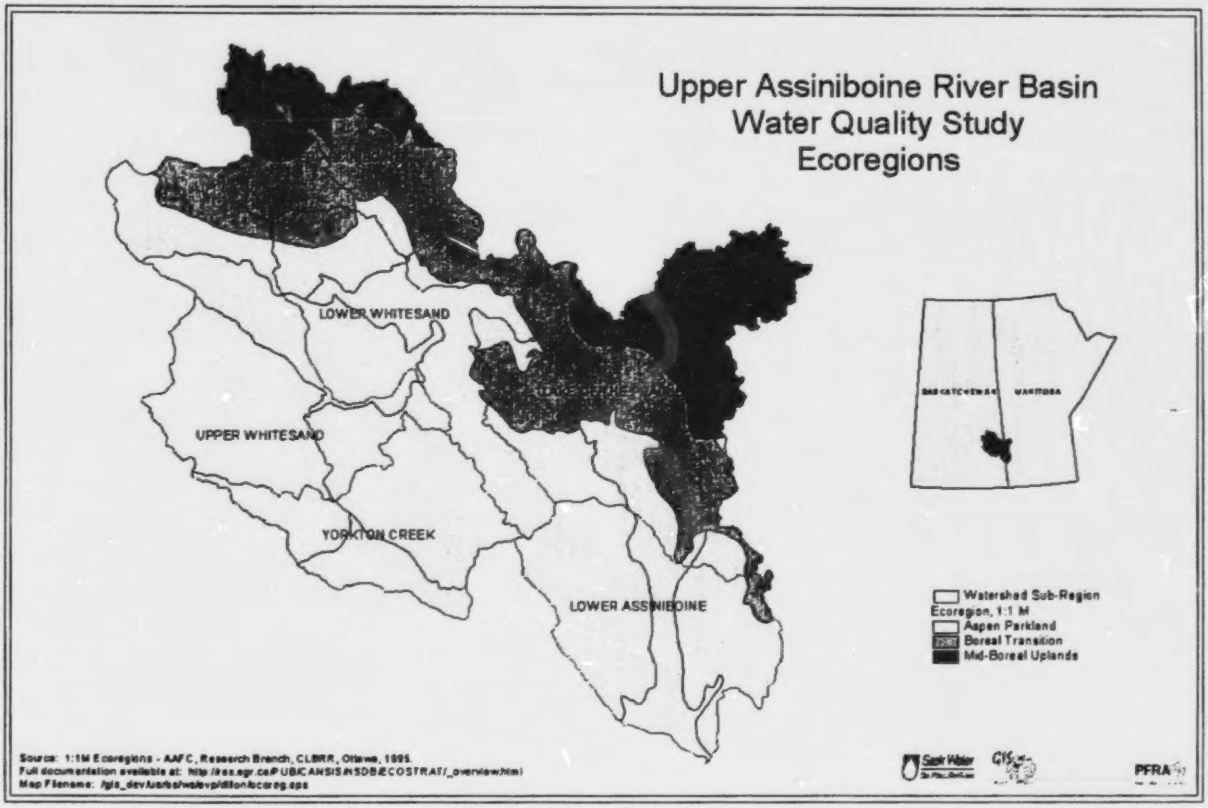
The study area is situated primarily in the Aspen Parkland Ecoregion (Figure 4), which is a transitional zone between the boreal forest to the north and grasslands to the south. Figure 5 displays a map of land cover. While most of the vegetation has changed due to agricultural practices, native vegetation typically consists of fescue and mixed-grass prairie in the uplands and river valley floors, interspersed with aspen groves. Aspen groves with mixed shrubs are still common, while stream and river valley walls support a wide variety of tree species including balsam poplar, white birch, Manitoba maple, green ash, American elm and cottonwood. Common understorey shrubs are red osier dogwood, willow varieties, pin cherry, highbush cranberry, saskatoon, and snowberry (Ecological Stratification Working Group, 1995).

The vegetation in the Aspen Parkland Ecoregion provides habitat for a number of animals such as white-tailed deer and moose. Other large mammals occasionally seen in the area include red fox, coyote, and black bear. Beaver, red squirrel, Franklin ground squirrel, badger, raccoon, porcupine, snowshoe hare and skunk can also be found. Common bird species include the great horned owl, ruffed and sharp-tailed grouse, hawks, geese and ducks (Ecological Stratification Working Group, 1995).

The study area provides regionally and locally important breeding, molting, and staging habitat for a wide variety of waterfowl and wetland bird species. Ducks find staging and breeding sites on the Whitesand River Plain, the Touchwood slope, and the plains and lakes in the Yorkton area. Dabblers prefer marshlands while divers prefer larger open water sites. Both require secure habitat during nesting period and molting-post-breeding flightless periods. Colonial water birds such as the Double Crested Cormorant, the Black Tern, and American White Pelican rely on the habitat within the Upper Basin for spring and fall staging as well as summer foraging and roosting sites. For Canada and Lesser Snow Geese parts of the study area, such as Margo Lake area, provide important staging and molting sites. The Yorkton lakes and Good Sprit Lake also provide habitat for breeding pairs (Poston et al., 1990).

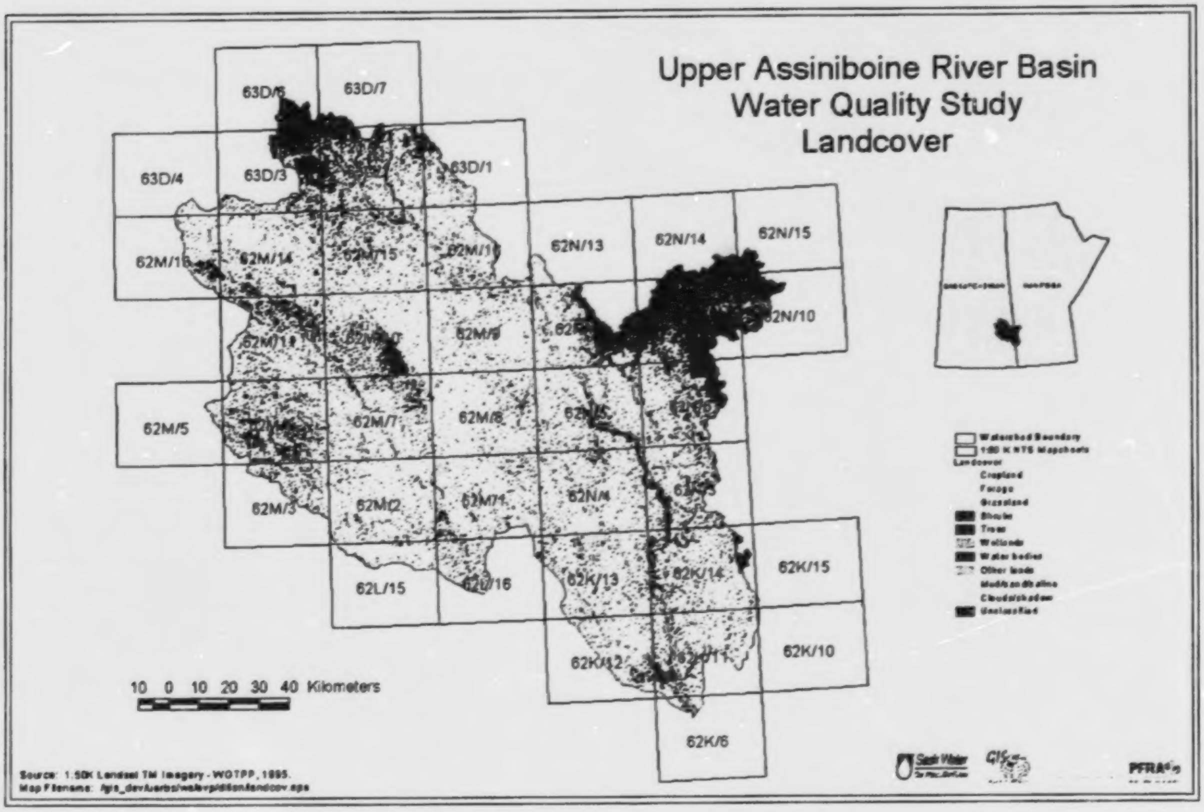
The basin provides habitat for species categorized as endangered or threatened by the provincial and federal governments or agencies such as World Wildlife Fund. Three threatened wetland bird species in the Upper Assiniboine Basin, the Piping Plover, Great Blue Heron, and the White Pelican, rely on various wetlands and surface water bodies for habitat. Like other shorebirds, Piping Plover habitat is susceptible to grazing practices that allow cattle to disturb shallow wetland areas, as well as other agricultural practices (Poston et al., 1990). This region also contains the Great Plains Toad and Northern Leopard Frog that, like most amphibians, are highly sensitive to water quality changes. The Small Yellow or Fremont's Monkey-Flower is a rare species of vegetation whose habitat is running streams (Looman and Best, 1987) that has the potential to be affected by water quality changes such as sediment loading.

Figure 4 Ecoregions


Upper Assiniboine River Basin
Water Quality Study
Ecoregions
LOWER WHITESAND
UPPER WHITESAND
YORKTON CREEK
LOWER ASSINIBOINE
SASKATCHEWAN
MANITOBA
▭ Watershed Sub-Region
Ecoregion, 1:1 M
▭ Aspen Parkland
▨ Boreal Transition
■ Mid-Boreal Uplands
PFRA

Source: 1:1M Ecoregions - AAFC, Research Branch, CLBRR, Ottawa, 1995.
Full documentation available at: http://res.agr.ca/PUB/CANSIS/NSDB/ECOSTRAT/_overview.html
Map Filename: /gis_dev/usrbs/wsievp/dillon/ecoreg.eps

Figure 5 Landcover


Upper Assiniboine River Basin
Water Quality Study
Landcover
63D/6
63D/7
63D/4
63D/3
63D/1
62M/16
62M/14
62M/15
62M/10
62N/13
62N/14
62N/15
62N/10
62M/11
62M/10
62M/9
62M/5
62M/7
62M/8
62M/3
62M/2
62M/1
62N/4
62K/15
62L/15
62L/16
62K/13
62K/14
62K/12
62K/11
62K/10
62K/6
Watershed Boundary
1:50 K NTS Mapsheets
Landcover
Cropland
Forage
Grassland
Shrubs
Trees
Wetlands
Water bodies
Other lands
Mudflats and Saline
Cloud/shadow
Unclassified
10 0 10 20 30 40 Kilometers
Sask Water
GIS
PFRA

Source: 1:50K Landsat TM Imagery - WQTPP, 1995.
Map Filename: /gis_dev/uarbs/wqtpp/dillon/landcov.eps

While all terrestrial species experience negative impacts from water sources contaminated with pesticides and toxic wastes, bird, amphibians and reptiles, and aquatic mammal species are often more directly affected because of diets based on aquatic plants, invertebrates, and fish. In addition, a variety of agricultural activities can create changes to shorelines that provide habitat for other aquatic biota such as amphibians. Currently, there is little if any biomonitoring of terrestrial, waterfowl or shorebird species in the vicinity of the study area to observe and document the presence and movement of contaminants through the ecosystem (Poston et al., 1990).

1.3.6 Aquatic Biota

All fish and aquatic biota are protected under various federal and provincial legislations. The post-spawning and early stages of fish are typically the most sensitive in terms of susceptibility to changes in water quality.

Sport fish in the Assiniboine River basin include walleye, sauger, and channel catfish (Natural Resources, 1992; Stewart, 1991) and the swift-flowing rocky sections are important spawning and rearing areas. Walleye and sauger spawn in the early spring months, whereas channel catfish spawn in the late spring or early summer (Scott and Crossman, 1973). There is a resident population of walleye in the Shellmouth Reservoir, which spawn in the Upper Assiniboine River near the Saskatchewan border (Derksen, pers. comm., 1991). This reservoir has been stocked with walleye, yellow perch, smallmouth bass, and muskellunge (Natural Resources, 1992).

Northern pike are also spring-spawning species in the Assiniboine River and prefer slow-moving weedy areas to spawn. Goldeye, mooneye, and yellow perch are also found in slow-moving, weedy areas, where they spawn in the spring. Burbot are also found in the Assiniboine River; but since they prefer lake spawning, adults would not be found in the river during the winter spawning period.

Other fish species in the Assiniboine River include the rock bass, central mudminnow, stonecat, carp, bigmouth buffalo, black bullhead, brown bullhead, trout perch, white sucker, shorthead redhorse, freshwater drum, and several shiner, dace, and darter species (Sask Water, 1995; Natural Resources, 1992; Stewart, 1991). Most of these species spawn in late spring or summer. The chestnut lamprey and bigmouth buffalo (a sucker species) are fish species in the Assiniboine River classified as "vulnerable" by The Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Both species spawn in tributary streams in the spring (May to June) with the lamprey preferring coarse gravel areas, and the bigmouth buffalo preferring flooded wetlands (Scott and Crossman, 1973).

Many of the intermittent streams in the study area do not provide sufficient habitat to sustain aquatic species. These creeks experience high flows during the spring, but during the rest of the year the aquatic habitat is reduced to small, isolated pools and marshy areas. While these provide habitat for other biota (such as waterfowl, etc., discussed previously), fisheries resources are minimal to nonexistent. However, some of the creeks are accessible, for fish, along their lower reaches during the spring. Spring-spawning species, such as northern pike, white sucker, and walleye, may migrate part-way up some of these creeks to spawn if spring flows are sufficient.

Although fish are the most high-profile biota in the Assiniboine River, there are a variety of other species that are less mobile. While algae species often cause problems through overgrowth in reservoirs and slow-moving watercourses, aquatic vegetation provides essential habitat for a variety of organisms, including fish species. There are a variety of aquatic invertebrate species that use other niches. The species' composition and abundance of these aquatic communities are highly dependent on the quality and quantity of water. Most species of invertebrates reproduce in the summer months when water temperatures are conducive to rapid development. An example of invertebrate biota is the freshwater mussel. Most mussel species spawn from May to August, when water temperatures exceed 18°C (L. Roberts, pers. comm., 1991). Other than their planktonic larval stage, mussels are relatively immobile species and are sensitive to suspended solids and pollutants. Of particular concern in the future will be the potential introduction of the zebra mussel, presently expanding its range beyond the Great Lakes, where it was introduced in 1985. These molluscs pose threats to water distribution systems through growing within and clogging intake pipelines (Dillon, 1991).

2.0 PARAMETERS OF CONCERN

2.1 General

This report documents the potential effects from a number of activities occurring in the Upper Assiniboine River Basin. These activities include a number of agricultural activities, such as cropping, field runoff and drainage, livestock and range management. They also include activities such as municipal lagoon discharges, septic system operation, and contaminated sites. These activities have the potential to affect surface and/or ground water, through the generation of contaminants. In this section, the following water quality parameters of primary concern are discussed:

- Nutrients (nitrogen and phosphorus)
- Dissolved Oxygen
- Pesticides
- Heavy Metals
- Turbidity/Sedimentation
- Pathogens

For each parameter, a description is provided that introduces the parameter and explains why it is a concern. In addition, where possible, the status and trends of the parameter are presented for both surface and ground water.

The description also provides the current water quality guideline/criteria for each parameter. Water quality guidelines and objectives have been developed by provincial and federal agencies in their efforts to assess water quality problems and manage competing uses of water resources (CCME, 1987). In order to quantify the magnitude of water quality problems, these agencies have defined acceptable levels of quality for specific water uses. These uses include drinking water, recreation and aesthetics, agriculture (e.g., livestock watering, irrigation), and freshwater aquatic life. Criteria based on scientific research are used to develop guidelines, which are recommended values of quality. Guidelines can be refined to form site-specific water quality objectives or can be modified, if necessary, and enshrined in law to become standards.

National water quality guidelines have been developed by the Canadian Council of the Ministers of the Environment (CCME, 1987) and in conjunction with Health Canada (Dorian, pers. comm., 1997). The CCME (1987) guidelines are comprehensive, including those for drinking water, recreational use, livestock watering, irrigation, industrial use, and freshwater aquatic life. Health Canada may also set standards regarding human exposure to hazardous elements based on acute exposure (Dorian, pers. comm., 1997). Recommended guidelines for nutrients, pesticides, trace metals, pathogens, and suspended sediment levels that are likely to be affected by activities in the basin are discussed in the following sections, with details provided in Appendix 1.

Water quality is monitored by the Prairie Provinces Water Board, Sask Water, and Manitoba Environment within their various jurisdictions, and also by Environment Canada. The Prairie Provinces Water Board has established transboundary water quality objectives for the Assiniboine River at Kamsack (PPWB, 1992). The water quality of the river, as it flows from Saskatchewan to Manitoba, is expected to meet the guidelines outlined in Appendix 2.

The provincial guidelines are often similar to their national counterparts. Where provincial guidelines do not exist, the national guidelines are usually referenced. An overview of Manitoba and Saskatchewan objectives for parameters commonly affected by agriculture, waste disposal, and point source pollution activities in the basin are outlined in Appendix 1. The Manitoba Department of Health and Safety and Saskatchewan Health may also establish guidelines regarding human exposure to hazardous elements.

2.2 Nutrients

2.2.1 Description

Nutrients entering surface and ground water supplies from external sources such as agricultural fertilizer, livestock manure, wastewater, and municipal sludge, can impact water quality, creating negative consequences for wildlife, livestock, human, and aquatic biota. These have been shown to have the potential to cause eutrophication and elevate nitrogen and phosphorus levels by entering water supplies through surface runoff, direct disposal, or leaching to subsurface water supplies.

Eutrophication

Eutrophication is the process by which water bodies become biologically more productive as a result of an increase in nutrients. This is a natural process that normally takes decades to occur. However, human activities can greatly increase the rate of eutrophication through nutrient loading, particularly phosphorus, of surface water bodies such as rivers, streams, and lakes (Environment Canada, 1986; Osei, et al., 1994)

One of the byproducts of excessive nutrients in water bodies is the stimulation of algae growth, which has a number of environmental implications. Changes in aquatic populations have been known to occur as a result of excessive algae growth. Algae blooms can serve to limit light penetration necessary for submerged aquatic vegetation. This can affect the habitat for a variety of vertebrate and invertebrate species that rely on the aquatic vegetation for food and cover from predators (USCATST, 1992). Spawning areas of traditional fish species can be destroyed because of reduced water flow due to algae growth and lower oxygen levels occurring during decomposition of the algae. The invertebrate community may shift to different species and the foraging success of some fish such as salmonids may deteriorate (Tones, 1987).

Algae can be very damaging to aquatic environments after they die and begin to decompose. The bacteria that decompose the algae require oxygen. When excessive algae growth has occurred, the bacterial demand for oxygen creates conditions where insufficient dissolved oxygen is available to support fish and invertebrate populations. The result can be widespread fish kills, such as that which occurred in the Upper Assiniboine Basin at the Lake of the Prairies in the early 1970s (Moenig and Lakatos, 1976). An eleven-week algae monitoring program to estimate growth and species types at Lake of the Prairies Reservoir was able to correlate fish kills below the dam site to high levels of algae in the reservoir (Moenig and Lakatos, 1976). To minimize eutrophication, the PPWB has set a guideline of 0.5 mg/L for phosphorus (PPWB, 1995).

Excessive algae growth can also impair recreation activities by being aesthetically unpleasant and having negative implications for human health. Unpleasant odours emitted during algae growth periods and changes to water texture imparted by algae, deter recreation. Large blooms reduce clarity and therefore safety for swimmers and other users and skin irritations may also result (Tones, 1987).

Algae may negatively impact drinking water quality by imparting odour and taste (Tones, 1987). What is more important, when certain species of blue-green algae decompose (such as *Microcystis aeruginosa, Anabaena flos-aquae* and *Aphanizomenon flos-aquae),* compounds are released that can prove highly toxic to humans, livestock and wildlife (Petersen, 1991; ECA, 1982; White, 1978; Worthington, 1977; Tones, 1987) and long-term exposure may promote liver cancer or even death. Some studies indicate that fish mortality may also result from toxic algae (Gurney and Jones, 1997). Toxins can be actively released by some algae species. Two types of toxins can be generated, depending on the species. These are hepatotoxins (polypeptides) and neurotoxins (alkaloids). The alkaloids affect the nervous system causing suffocation and the polypeptides lead to rapid degeneration of organs (CCME, 1987).

Predicting toxicity arising from the algae species is difficult due to the complex circumstances involved in the formation of toxic conditions. The environment must be suitable for toxic algae growth and toxic strains must dominate nontoxic strains. In addition, the spatial distribution of the toxic algae may also be concentrated by wind action. If minimal mixing occurs in the waterbody, then the toxicity will greatest at that one location. Toxicity levels also differ depending on algae species type and age (CCME, 1987).

Health Canada has set the interim drinking water quality guideline for Microcystin-LR (a hepatotoxin) at 1.5 µg/L. No limits currently exist for livestock watering (Gurney and Jones, 1997). Conventional water treatment technology commonly found in rural Manitoba and Saskatchewan does not appear to remove significant levels of microcystin LR from drinking water (Gurney and Jones, 1997). There are no guidelines currently in place for other algae.

There are a variety of chemicals that can control algae growth, including copper sulfate, xylene, and acrolein (Boyd, 1975); however, these chemicals can also degrade water quality. The use of calcium carbonate or "lime" is becoming popular in Alberta as a method of controlling algae, and the liming of dugouts appears to offer a relatively safe control method (Buchanan, 1991).

Nitrogen

Nitrogen is a necessary element for animal and plant growth. It is naturally found in high concentrations in the atmosphere, soil, plants, and occasionally in ground water. It occurs in fresh water in a variety of forms including dissolved nitrogen (N_2), ammonium (NH_4^+), nitrite (NO_2^-) and nitrate (NO_3^-). Human activities strongly influence the magnitude of nitrogen loading of surface and ground waters. Generally, because the element is abundant naturally, nitrogen loading of fresh water bodies is often not as great a concern to aquatic life as phosphorus loading (Gregor and Chacko, 1987). However, concentrations of nitrogen in ammonia form can be toxic to various aquatic biota. Naturally occurring ammonia concentrations seldom exceed 0.1 mg/L, a level typically tolerated by aquatic life. However in alkaline conditions, concentrations as low as 0.01 mg/L may be harmful to aquatic life (CCME, 1987). Consequently, national and provincial water quality guidelines set ammonia limits according to pH levels (Appendix 1) (CCME, 1987; PPWB, 1992; Williamson, 1988a). Higher temperatures further increase the toxicity of ammonia (Frank, 1997). Ammonia reduces the oxygen carrying capacity of blood leading to kidney and liver damage, as well as reducing growth rates, lowering hatching success and increasing mortality in fish fry (CCME, 1987). Conditions of high ammonia concentrations are likely to be generated from municipal waste systems, septic tanks, manure or fertilizer runoff (Green, 1996).

Ammonia nitrogen along with nitrate/nitrite can also stimulate the growth of algae and aquatic plants. Ammonia readily converts to nitrate plus nitrite in water through a chemical reaction with dissolved oxygen (Beck, 1996). Manitoba and Saskatchewan have recommended that nitrate plus nitrite be limited to protect human health (Williamson, 1988a; SERM, 1997). Nitrate/nitrite rarely reaches the PPWB 10 mg/L criteria (nitrate/nitrite reported as N) limit due to denitrification in surface waters (the process of converting nitrate and nitrite to gaseous nitrogen by microorganisms). When this process occurs in water, it has the potential to deoxygenate the water, stressing fish and other aquatic biota due to microorganism oxygen demand. Levels exceeding 10 mg/L result from extreme nitrogen loading (Beck, 1996).

High levels of nitrogen, (above 10 mg/L nitrate/nitrite reported as N) can create human health problems such as methemoglobinemia in infants (USCATST, 1992). This blood disorder is commonly called blue-baby syndrome: the infant's lips and body take on a marked blue hue. Bacteria, within the feeding bottle or the child's body convert nitrate into nitrite, which the hemoglobin in the blood takes up rather than oxygen. The condition may lead to respiratory failure (Saull, 1990).

The Federal-Provincial Drinking Water Sub-Committee of the Federal-Provincial Committee on Environmental and Occupational Health (CCME, 1987) has set the drinking water guideline for nitrogen at 45 mg/L (based on nitrate/nitrite reported as NO_3) and nitrite at 3.2 mg/L. Manitoba's surface water objective for nitrate/nitrite is 10 mg/L (as N). Saskatchewan's objective is set as 45 mg/L (as NO_3). It must be noted that these two levels are actually equal to each other due to the method in which they are expressed. In farm animals, excessive levels of nitrogen can result in weight loss and poor feed conversion (USCATST, 1992; The CCME, 1987). As a result, the CCME (1995) livestock watering guidelines are 100 mg/L for nitrate and 10 mg/L for nitrite. Saskatchewan surface water objectives for livestock watering are 100 mg/L for nitrate/nitrite.

It must be noted that the guidelines for nitrogen were established to prevent direct toxic effects to human consumers. If these objectives are not exceeded, there may still be risks of eutrophication, since they were not established for this purpose. For a comparison of national and provincial nitrate, nitrite and nitrate plus nitrite guidelines, see Appendix 1.

Phosphorus

Relatively small amounts of phosphorus occur in aquatic systems naturally since it is a nutrient readily taken up by plants. While it has no direct impact on livestock or human health, phosphorus has implications for freshwater aquatic ecosystems. In water, phosphorus is continually changing due to the process of decomposition and synthesis, modified by various physical, chemical, and biological factors (CCME, 1987). Two forms of phosphorus in water are of interest: total phosphorus and dissolved phosphorus. Total phosphorus consists of suspended particulate and dissolved phosphorus. Suspended phosphorus is bound to organic particles such as top soil and is released in a water solution, enhanced by a variety of processes such as bacteria interactions and agitation from turbulence (Gregor and Chacko, 1987). In its dissolved form, phosphorus is readily uptaken by plants and algae (Beck, 1996).

Biological activity in freshwater is sometimes controlled by the input loading of phosphorus from external sources such as agricultural fertilizer in runoff. Unlike nitrogen, which is more likely to leach, phosphorus binds with the soil structure and thus is unlikely to enter ground water supplies. Phosphorus enters surface water through runoff or with eroded soils where it is easily mobilized and released into the surrounding aquatic environment (OECD, 1991; Gregor and Chacko, 1987). Phosphorus is often a greater concern for aquatic systems than nitrogen because it generally is considered the limiting factor for the growth of freshwater phytoplankton such as algae (CCME, 1987). Elevated levels in water can increase aquatic weed growth and result in eutrophication (Fisheries and Oceans, 1992). Increases in weed growth can limit foraging options for fish and make water less attractive and safe for recreational use (Tones, 1987). Phosphorus guidelines are usually defined as "free from nutrients in concentrations that create nuisance growths of aquatic weeds or algae that result in an unacceptable degree of eutrophication of the receiving water" (SERM, 1997). The phosphorus guideline for the Assiniboine River at the provincial boundary is 0.5 mg/L. Appendix 1 contains the national and provincial guidelines.

2.2.2 Status and Trends

Surface Water

Nitrogen

Farms presently use about 35 times more fertilizer than they did in the 1950s (Fisheries and Oceans, 1992), which creates increased opportunity for nutrient loading in surface and ground waters. Prairie river basins show a seasonal and annual variation in the levels of nitrogen in surface water (Saskatchewan Environment and Public Safety, 1992).

Higher levels of nitrogen were recorded downstream of Kamsack following spring and fall lagoon discharges. During spring releases from the Kamsack lagoon, ammonia levels were above the Saskatchewan's provincial surface water quality objectives (Saskatchewan Environment and Public Safety, 1992).

An analysis of the Assiniboine River at Kamsack (Dunn, 1995) found that total nitrogen concentrations decreased by a significant rate between 1973 and 1993. The range was between 0.34 mg/L and 4.9 mg/L, which is below the PPWB objective of 10 mg/L (PPWB, 1992). In this long-term analysis, the objectives for nitrite/nitrate and ammonia were met 100 percent of the time (PPWB, 1997). Spring months tend to experience the highest levels with much lower levels seen in the fall and winter. These trends indicate that increases may be due to agricultural runoff events as well as municipal lagoon discharges (Saskatchewan Environment and Public Safety, 1993).

In an extensive study of agricultural water quality in Alberta, it was found that both phosphorus and nitrogen levels exceeded water quality guidelines for the protection of aquatic life in streams in the vicinity of high intensity agricultural activities (CAESA, 1998).

One important note is that similar concentrations of the same nutrient may not have the same biological effect in different rivers, and river-specific objectives may be necessary (P. Chalmers, NHI, in PPWB, 1997). In addition, Harker (1997) cited research indicating that high nitrate levels have been attributed to geologic and not agricultural sources.

Phosphorus

Surface waters in agricultural areas show a seasonal and annual variation in the levels of phosphorus in surface water. Elevated levels of phosphorus have been measured downstream of effluent discharges from Kamsack lagoon (Saskatchewan Environment and Public Safety, 1997) and Yorkton wastewater treatment plant (SERM, 1995 data files). For Kamsack, high phosphorus loadings during low flow years made a significant impact on the percentage of phosphorus in the downstream watershed (Saskatchewan

Environment and Public Safety, 1997). For the Assiniboine River at Kamsack, the data from 1974 to 1993 indicates that during this time period, the total phosphorus objective of 0.05 mg/L set by the PPWB was regularly exceeded (Gregor and Chacko, 1987; PPWB, 1992).

Phosphorus loadings are likely due to agricultural runoff events and municipal lagoon discharges (Saskatchewan Environment and Public Safety, 1997). Increased drainage and sediment loadings also influence phosphorus levels. Part of the basin lies in a highly phosphorus-deficient zone, particularly on areas of sandy soils; as a result, phosphorus inputs may be elevated (Roberts and Green, 1995).

Algae and Weed Growth

It appears that there have been few published algae studies specific to the basin. Moening and Lakatos (1976) conducted an eleven-week study in the early 1970s on the impact of algae on fish kill on the Assiniboine River at Lake of the Prairies. Reservoir algae populations were believed to consist of low species diversity, dominated by various blue green algae and few green algae species. The growth and subsequent collapse of the algae populations were correlated with changing water levels, storm and wind activity, and phosphorus levels. Persistently high levels of phosphorus inputs continue to support the growth of algae at Lake of the Prairies (Dunn, 1995). It should be noted that since surface waters generally have levels of phosphorus higher than required for algae growth and lower nitrate levels than needed for algae growth, blue-green algae can have a competitive advantage. This is because these species can fix atmospheric nitrogen and are therefore not limited by the nitrogen levels in the water. Many of these species can also be toxin producers.

A recent study by Manitoba Environment (Gurney and Jones, 1997) reviewed the occurrence and distribution of toxic algae strains in Manitoba. The Lake of the Prairies reservoir has levels below the interim national guidelines for the toxin microcystin. This toxin is resistant to most domestic and municipal treatment systems used in the basin and toxic concentrations can persist during winter months. Toxic algal blooms elsewhere in the province have caused the deaths of animals and health problems in humans in recent years (Gurney and Jones, 1997). The York Lake Study (UMA and the Environmental Applications Group, 1981) also identified large algae blooms associated with nutrient loading.

Ground Water

Nitrogen

As mentioned previously, farms use as much as 35 times more fertilizer as they did in the 1950s (Fisheries and Oceans 1992) which creates increased opportunity for nutrient loading of surface and ground waters. Unlike phosphorus (discussed later), nitrate-nitrogen is highly susceptible to leaching. Once it has leached below the root zone of crops it accumulates in soil because there is seldom enough carbon for effective denitrification to occur. Denitrification is the reduction of nitrogen by organisms using carbon under anaerobic or aerobic conditions (Oleszkiewicz, 1995). Nitrate is difficult to remove with standard water treating equipment, requiring expensive and sophisticated systems to do so (Banias, 1977). However, in ground water, nitrate is mobile, and research has shown that it dissipates with depth (Domyaha, 1994).

A recent survey of agricultural fields in Manitoba indicated that in approximately 20 to 35 percent of fields sampled (depending on the fertilizer application and tillage system), nitrate leached down past the root zone of 1.3 m. Nitrate levels in the upper 1.3 m were above 150 pound/acre, which greatly exceeds the requirements of annual crops (Ewanek, 1995). A study of shallow ground water aquifers in southern Saskatchewan (Vogelsang, 1997) also found that approximately 35 percent of 186 wells tested had nitrate concentrations that were excessive. These exceeded the maximum acceptable concentration of 10 mg/L (as N) (CCME, 1987) by an average of 10 percent. Wells with the highest concentrations had cattle operations nearby (Vogelsang, 1997).

There were no published studies found which address nitrate leaching to ground water supplies in the basin. However a number of ground water samples have been collected and studies undertaken at specific locations to test drinking water quality of local aquifers for municipalities. Occasionally, these studies highlight contamination or opportunities for contamination of ground water supplies. For example, high nitrate content was reported in wells near Kamsack, but it was unclear if the nitrate was being leached from nearby fields due to fertilizer use or cattle manure (Banias, 1977). Ongoing research at the University of Saskatchewan indicates that it may be possible to determine the source of nitrate depending on the ratio of isotopes (Campbell, pers. comm.). This will improve the ability of researchers to identify sources of nitrate contamination.

Phosphorus

Where it is a main concern for surface water quality, phosphorus contamination of ground water is highly unlikely. Due to its chemical nature, phosphorus is basically insoluble and cannot percolate through soil layers. Unless runoff directly enters the subsurface, phosphorus does not present a threat to ground water quality (Tones, 1987).

2.3 Dissolved Oxygen

2.3.1 Description

Dissolved oxygen is required by fish and aquatic invertebrates. Excess nutrient loading may reduce available dissolved oxygen content in water due to the biological oxygen demand of microorganisms digesting organic matter. Nutrients may be supplied by runoff or stimulated by nutrient loading from human activities that can cause excessive weed and algae growth to occur Low dissolved oxygen levels, in particular, may negatively affect fish and some aquatic invertebrates and enhance the negative impact of contaminants on aquatic biota (CCME,1987).

The minimum dissolved oxygen levels required to protect coolwater fish is 5 mg/L (CCME, 1987). During the early stages of life, larval and juveniles are more sensitive to exposures of low dissolved oxygen levels. From spawning to 30 days after hatching, 6.5 mg/L of dissolved oxygen may be required in the water of the spawning bed and 9.5 mg/L in the water column. Little data is available on the effects of low dissolved oxygen levels on invertebrates, but it is believed that 5 mg/L should reasonably protect the majority of the invertebrate community (CCME, 1987). Another method of recommending dissolved oxygen limits is by the percentage of saturation, which Manitoba prescribes as 47 percent (Williamson, 1988a). Appendix 1 contains a list of national and provincial guidelines.

Low dissolved oxygen can increase the negative impact of toxic chemicals. Metals like zinc, lead, copper, and ammonia increase in toxicity in low dissolved oxygen. Higher temperatures also increase the adverse effects of low dissolved oxygen in fish by increasing metabolism (CCME, 1987).

2.3.2 Status and Trends

In general, oxygen levels in the basin exceed the 6 mg/L PPWB guideline (PPWB, 1992). Historical levels in the Assiniboine River were periodically low, but not below the guideline. The 1974 to 1991 data set at Kamsack, consisting of 210 samples, indicated that only 10 percent were less than 5.2 mg/L. A review of the Manitoba water quality data files yielded results consistent with Saskatchewan data. Several notable exceptions include a June 1973 level of 2.2 mg/L in the Binscarth area, and several low levels (0.8 to 4.9 mg/L) in the Shell River (e.g., Roblin area) from 1980 to 1982, usually in the spring. Typically, higher levels of dissolved oxygen have been observed since the low levels in the early 1980s. Only one exception was observed: the PPWB station at Kamsack yielded a level of 3.3 mg/L in February 1991.

As indicated previously, lower oxygen levels are likely related to higher nutrient levels in the system. Improved municipal treatment facilities may explain the apparent improvement in oxygen levels since the early 1980s.

2.4 Pesticides

2.4.1 Description

Surface Water

There are numerous types of pesticides used in the basin, as can be seen in the list in Appendix 3. Pesticides are chemical compounds used to protect crops and rangelands from excessive weed growth and insect infestation in the basin. In this study, pesticides refer to herbicides, insecticides, and fungicides. Insecticides are used to control insect infestations. Herbicides are a type of pesticide designed to control undesirable vegetation growth such as annual and perennial weeds (Peru, 1996). Fungicides are used (on only a few crops in the region) to control fungal growth in crops.

These chemicals can enter water sources from accidental spills, over drifts, incorrect application, or cleaning too close to surface waters. In addition, pesticides can run off fields following rainstorms and/or leach to ground water supplies over time (Coker, 1995). CCME (1987), SERM (1997), and Manitoba Environment (Williamson, 1988a) have established guidelines for pesticide compounds for drinking water, freshwater aquatic life, irrigation, and livestock watering. A list of those commonly used in the basin is found in Appendix 3. All criteria for pesticide residues in water for all uses are less than 1.0 mg/L.

Pesticides are an important component of modern farm production on the prairies (Honeycutt and Schabacker, 1994). However, these chemicals have implications for surface and ground water quality. Depending upon the chemical interactions with the prairie environment, some pesticides may persist in soil and water for long periods, working their way into the food chain to influence human, as well as aquatic and terrestrial vegetative and animal health.

Pesticides are usually more of a concern through direct application to the water surface. They tend to persist longer in soils and, if applied to soils, would not readily enter the water (Worthington, 1977). Most pesticides are also broken down by microbial action near the soil surface (Bouwer, 1987).

Both the parent pesticide compound and subsequent breakdown products may present concerns (Canter, 1987). The effects of chronic exposure to humans, livestock and terrestrial and aquatic ecosystems from such chemicals are not well understood (Gummer, 1979).

Insecticides can be divided into two groups: organochlorides and organophosphates/carbamates (OECD, 1991). Organochlorides such as endosulfan, dieldrin, and DDT are very toxic to fish and birds and tend to bioaccumulate in the food chain. Consequently, many of the original organochlorines pesticides are now banned. Organophosphates and carbamates are only moderately persistent in the environment. Since they do not bioaccumulate, they are gradually replacing organochlorides as the preferred pesticides (OECD, 1991).

A list of pesticides used in the Upper Assiniboine River Basin and their CCME (1987) and provincial guidelines can be found in Appendix 3. The PPWB (1992) outlines levels for only the herbicides 2,4-D, and 2,4,5-TP and the pesticide lindane (see Appendix 3).

Research has indicated that the transformation of pesticide products in the aquatic environment can significantly alter the toxicity of the compound. As a general trend, dilution by water tends to reduce the toxicity of the product. The critical factors in evaluating the transformation of pesticide products in the aquatic environment are exposure time, rates of appearance and disappearance, residual concentrations, and means of transformation (Maguire et al., 1988). Most products transform via chemical or biological means soon after application. The rate is dependant upon the chemical compound itself and other influential factors in the surrounding environment (Honeycutt and Shabacker, 1994). For example, some chemical compounds are affected by soil type and moisture content, exposure to light, varying pH levels and temperature (Pierce and Wong, 1988). These characteristics can also impact the tendency of the pesticide to leach. This tendency is influenced by the chemical's solubility in water, its half-life in soil and its ability to bind to soil particles. The list of common herbicides used in the Upper Assiniboine River Basin is found in Appendix 3.

Ground Water

Ground water contamination occurs when pesticides move through the unsaturated zone and reach ground water before being decomposed by chemical or microbial activity. Downward migration of pesticides primarily occurs with the assistance of water flow and is called leaching. Heavy rainstorms can contribute to downward leaching (Miller et al., 1992). Depending upon the chemical interactions with the prairie environment, some pesticides have been shown to persist in ground water for long periods.

The propensity for agricultural chemicals to contaminate surface and ground waters is dependant upon a number of factors, including environmental fate of the chemical, opportunities to reach water sources, and rate of transfer. The chemical characteristics of individual pesticides such as the rate of decomposition, solubility and soil adsorption capacity persistence, use patterns (frequency and timing of irrigation, rainfall, etc.) and rate of plant uptake, influences how the pesticide travels and its persistence in the environment. The mode and rate of application also influence a chemical's ability to contaminate surface and ground water sources (Yarish, 1992). Generally speaking, surface applied chemicals have a greater tendency for runoff, while incorporated chemicals have greater opportunity to leach to subsurface water. Aerial spraying has greater potential than surface spray applications to drift directly onto water bodies. The particular environment in which it is applied also influences the pathway options and environmental fate of the chemical. Micro-climatic conditions such as wind and rain, soil type and chemistry, as well as tillage practices and soil moisture content can affect the movement of pesticides and their persistence (Honeycutt and Schabacker, 1994; Currie and Williamson, 1995).

As mentioned previously, one of the primary concerns and challenges in assessing pesticide impacts is that they can persist in soil for months before being released into surface and ground water during heavy spring runoff or rainfall events (McNaughton and Crowe, 1995). This is confirmed through an Alberta study (CAESA, 1998), which found that levels increased in the spring after snowmelt. This was attributed to persistence in soil.

2.4.2 Status and Trends

Surface Water

Pesticide use in the basin is not well understood due to the lack of data on the type and amount applied in the region. Manitoba's and Saskatchewan's agricultural departments do not collect this data, but rely on chemical companies to supply information on type and amount sold in each province as a whole (Galowsky pers. comm., 1997). According to Manitoba Agriculture (1991), more than 20 million kg of pesticides are used annually in the prairies (mainly herbicides), with 45 percent being used in Saskatchewan alone. Prairie use accounts for 76 percent of the total pesticides sold annually in Canada (CPI, 1995). However, the annual herbicide use per hectare on the prairies is relatively small (Paterson, 1992). Since information on use is not specific to the basin, the potential for pesticide contamination of surface and ground waters in the Upper Basin resulting from agricultural application is unknown at this time.

In general, because of the shorter and dryer growth season on the Canadian Prairies, the use of pesticides and their potential to leach has been well below that of the United States or Eastern Canada. Therefore, the basin should be at lower risk of contamination from pesticides (Van der Kamp, 1989; Harker, 1997). However, this may be offset by the dry, cold climate which can mean slower degradation of chemicals and more erosion and concentrated leachate and runoff during periods like the spring or heavy rain storm events (Harker, 1997). For example, 2,4-D was detected in the winter at high levels in Alberta's surface waters, indicating that it degrades slowly in Canadian Prairie winter conditions, being inhibited by colder temperatures and lower dissolved oxygen levels (Gummer, 1979).

Approximately 75 percent of pesticide products listed in both Manitoba's and Saskatchewan's crop guides are applicable to crops grown in the basin. Approximately one third of the herbicides listed are restricted for mixing, loading, and/or application within a given distance of a water body due to their toxicity to aquatic species and potential to impact water quality negatively. While very few fungicides are restricted for use near water bodies, all pesticides are noted for being highly toxic to aquatic species. Toxicity levels for humans and livestock depend upon the individual product (Manitoba Agriculture, 1997; Saskatchewan Agriculture and Food, 1997a).

Gummer (1979) reported that pesticides were detected in surface water samples taken from an area encompassing the Upper Assiniboine River Basin, as well as the Red Deer River Basin. While such an extensive study area makes it difficult to determine which chemicals were found in the Upper Assiniboine, it does provide a general indication about what might be found. The following pesticides were detected: Lindane, MCPA, Silvex, 2,4-D, 2,4-DP 2,4,5-T. Lindane was also collected in fish samples taken from in Round Lake in the Qu'Appelle River Basin. Silvex contains dioxin and is no longer in use. MPCA migrates to surface water body sediments that may explain why it is not often detected in surface waters (Gummer, 1979). Pesticide levels were not provided by Gummer (1979), only frequency of detection.

A 1984 study was conducted by Manitoba Environment on pesticides in the Lower Assiniboine River Basin (Williamson, 1984). While this study is not specific to the study area, it does provide some indication as to kinds of pesticides found in the surface water of the Assiniboine River Basin. Twenty-seven pesticides were tested, including seven chlorinated phenoxy compounds, 14 organochlorines, seven chlorinated phenol compounds, and two organonitrogen pesticides. The study found measurable concentrations of the herbicides MCPA, trifluralin, and dicamba, but at levels below those posing a chronic threat to aquatic life or humans. The method of transportation was believed to be runoff from storm and meltwater events (Williamson, 1984).

A more recent study was published in 1995 on pesticides in the lower basin (Currie and Williamson, 1995). As with the 1984 study, the majority of samples were below national and provincial guidelines (Appendix 1) and few trends could be observed. Those detected with some regularity included the following:

- MCPA, with levels, which exceeded irrigation, aquatic life and livestock watering guidelines.
- Fenoprop, lindane, aldrin, and apha HCH with levels generally below guidelines.
- Trifluralin, with levels above the aquatic life objective.
- Dicamba, diclofop-methyl, and bromoxynil, with levels above the irrigation objective and with dicamba levels at one station exceeding the irrigation objective 100 percent of the time.

The only recent study specific to the Upper Assiniboine River Basin (Dunn, 1995) analyzed samples taken from 1973 to 1993 at the PPWB station at Kamsack. The results indicated that the majority of the herbicides and pesticides such as 2,4,5-T and 2,4-D were at levels below the PPWB objectives (PPWB, 1995).

Ground Water

Pesticides have been found in ground water samples across the Prairies, but usually in concentrations well below the Canadian Drinking Water Standards (Harker, 1997). However, the changes in tillage practices from conventional to reduced and conservation tillage systems, are changing herbicide use in a way that has implications for ground water quality. Overall herbicide use increases are expected to be between 15 to 60 percent. In addition, increased use of conservation and reduced tillage systems are expected to shift weed species from annuals to perennials that will cause a change in the types of herbicides farmers use. The adoption of conservation tillage regimes is expected to change the amount of herbicides that are used. This includes a decrease in soil incorporated herbicides such as trifluralin, which has little to moderate leaching potential, and an increase in the surface applied herbicides like glyphosate and 2,4-D (Monenco Consultants Limited, 1991). Trace amounts of herbicides such as 2,4-D have been found regularly in ground water supplies in recent years across the Prairie region (Harker, 1997).

It has been noted that leaching is most pronounced if a heavy rainfall occurs immediately following a herbicide application. Hill and Harker (1996) researched herbicide leaching into shallow ground water under non-irrigated conditions with soil high in organic matter at an Alberta study site. Leaching was discovered to be dependant upon timing of application, amount of rainfall, the herbicide's properties of persistence, water solubility, and its tendency to be absorbed into the soil. While glyphosate has little opportunity to leach because of its short half-life, others like 2,4-D and dicamba, followed by bromoxynil, MCPA and diclofop, are prone to leaching. Fenoxaprop was not detected while trifluralin and triallate had some leaching potential into shallow ground water. Levels of contaminants remained below Canadian drinking water standards (Hill and Harker, 1996).

One of the most recent studies on the Prairies (Vogelsang, 1997) was undertaken in southern Saskatchewan on shallow ground water aquifers that were highly sensitive to surface source contamination. It confirmed that pesticides are leaching into ground water at very low concentrations, which serves as an early indication of possible future water quality trends. Twenty-six percent of the 184 wells tested had some pesticides above the SERM Municipal Drinking Water Quality Objectives, but all were well below CCME guidelines and not considered a significant concern (Clifton Associates, 1997). The discrepancy in national and provincial guidelines is because SERM guidelines specify no detection of pesticides in drinking water, while CCME guidelines are based on best available science. Specific pesticides identified included Dicamba, MCPA, Atracine, Triallate, and 2,4-D.

The National Water Research Institute (Wood and Anthony, 1995) detected herbicides in water samples collected from springs across the Prairies. Springs, more than sampling wells, were found to be better indicators of contamination levels of the overall aquifer. Sampling of wells tends to indicate contamination of the well itself through handling and washing of pesticide and herbicide equipment nearby or from runoff that has penetrated the well from the surface. In contrast, springs represent contamination from infiltration due to leaching. Herbicide contamination of shallow ground water aquifers appears to be relatively infrequent, much less than indicated by well sampling.

The most frequently detected herbicides in Prairie springs were atrazine, picloram, 2,4-D, dichlorprop (2,4-DB) and simazine (Wood and Anthony, 1995). Minimal detections of triallate, diallate, metolachlor, Silvex, MCPB and bromoxynil also registered. All detections were at the ultra-trace level, far below those that would pose a significant health risk (CCME 1987, Wood and Anthony, 1995). Some of the herbicides, namely atrazine and simazine, were not used on land overlying the studied aquifer, leading to speculation that contamination occurred from atmospheric transport (Wood and Anthony 1995). Therefore, some chemicals not used extensively in the basin such as atrazine and simazine (Abrametz pers. comm., 1997), still represent a contamination risk for ground water sources.

Parts of the Assiniboine River basin have been identified as areas vulnerable to pesticide ground water contamination based on soil conditions, topography, land use, climate, and depth to ground water (McRae, 1991). These areas are a site west of Yorkton, a region along the Assiniboine River near Kamsack - from west of Sturgis to the Coté Indian Reserve, the region surrounding the Good Spirit Lake, and along the Manitoba/Saskatchewan boundary - from the northern tip of the Lake of the Prairies to the area near Binscarth.

2.5 Heavy Metals

2.5.1 Description

Heavy metals can be introduced to water sources from the application of manure or municipal effluent on agricultural land, the disposal of municipal sludge, and from point sources such as landfills, spill sites, and former industrial locations. Occasionally, heavy metals have been components in agrichemicals such as silver and mercury, which are found in many fungicides.

Due to their long half lives in organisms, bioaccumulation of metals can occur readily. The specific impact will vary with each metal, but they can cause a wide range of impacts in humans and are toxic at various threshold levels to wildlife, livestock, humans, and aquatic biota. Trace elements commonly found in wastewater include arsenic, barium, cadmium, chromium, lead, mercury, selenium, zinc, and nickel. Copper residues are also found at significant levels in hog manure (Beck, 1996).

Canadian drinking water quality guidelines (CCME, 1987) for most heavy metals are set as Maximum Acceptable Concentrations (MACs) for safe consumption over the period of a lifetime. Short-term water quality changes that exceed MACs will not necessarily result in negative health impacts unless levels remain above the recommended levels over a long duration. Other metals have been set at interim maximum acceptable concentrations until research is completed on their ability to bioaccumulate and biomagnify in the environment (CCME, 1987).

Impacts on humans, terrestrial, and aquatic biota vary with the individual substance and concentration levels, but may be responsible for birth defects, cancers, organ failures, and respiratory illnesses. Cadmium, for example, has a very long half life, concentrating in the liver and kidneys and is considered to be potentially carcinogenic (Kowal, 1985) to both terrestrial and aquatic species (Green and Beck, 1995). Other metals such as barium and copper are toxic at certain levels to aquatic species (SERM, 1997).

Mercury is highly persistent in the environment, accumulating in sediment and food chains at levels that may exert chronic toxicity to aquatic and terrestrial life, including humans (SERM, 1997). In the basin, unnaturally high mercury levels in predator fish from Lake of the Prairies Reservoir have been recorded (Green and Beck, 1995). Potential sources are industrial activities, and waste sludge as well as formerly used agricultural fungicides (Green and Beck, 1995). In addition, mercury can become bioavailable through bacterial processes that release methyl mercury from sediments in newly created reservoirs. Methyl mercury is released into the aquatic system in greatly elevated levels after prolonged flooding of sediments layers, which occurs when reservoirs are developed (Coker, 1995; Williamson and Ralley, 1993).

Mercury can move through the food chain. In the aquatic system, accumulation of mercury by organisms is variable, with those higher up the food chain usually having greater concentrations. Bottom feeders that absorb mercury from sediments also generally have rates higher than those feeding in the water column (CCME, 1987). Waterfowl that feed on mercury-contaminated biota experience impaired reproductive systems and neurological disorders (Scheuhammer, 1995). Fish are also one of the more direct routes for human consumption of significant quantities of mercury (Dumont, 1995). Recommended guidelines for mercury are 0.5 μg/g for fish consumption, 0.1 μg/g for commercially sold fish, 3 μg/L for livestock watering, and 1 μg/L for human drinking water (CCME, 1995).

Lagoon sludges generally have relatively high levels of metals due to long retention times and infrequent sludge removal. Excessively high levels inhibit microbial activity and are likely to enter the food chain (CCME, 1987). Studies of sludge application sites have shown trace elements tend to remain at the soil surface and not leach to ground water supplies (Kowal, 1985). However, CCME (1987) indicates that mercury can leach to ground water from industrial sites and landfills that contain batteries, paints, and other substances high in heavy metals. Ongley (1981) has also found trace metals in Alberta rivers emanating from municipal effluent and agricultural surface runoff. Appendix 1 contains a list of the national and provincial guidelines for those trace metals.

2.5.2 Status and Trends

The levels of trace metals in surface water at the PPWB sampling station at Kamsack are all below the PPWB limits and most are decreasing, except for manganese (PPWB, 1996). High manganese levels, which regularly exceed the current guidelines are naturally occurring in the Prairie region (CCME, 1987).

Manitoba Environment established a Biomonitoring Program to monitor trace metals in fish caught in the Assiniboine River from 1978 to 1992 (Green and Beck, 1995). This program was limited to the Manitoba portion of the Assiniboine River, with the majority of samples drawn from the Lower Assiniboine River Basin.

Mercury, arsenic, copper, zinc, and selenium residues were analyzed in sauger, northern pike, walleye, common sucker, and shorthead redhorse sucker muscle tissue at the Lake of the Prairies, Manitoba (Green and Beck, 1995). Most trace metals were below the laboratory detection limits. Levels of lead and selenium appear to be dropping and levels of copper, nickel, and zinc were well below consumption guidelines. Mercury was the only exception as levels were found to be above the national guideline of 0.5 μg/g for fish consumption and 0.1 μg/g for unlimited commercial sale of fish. These levels were greatest in predator fish such as walleye, sauger and northern pike, which indicate the biomagnification of mercury through the food chain.

One potential source of mercury in the lake was agricultural fungicides that in the past contained mercury which may persist in the aquatic environment. Other potential sources were landfill sites containing batteries, paints and other industrial sources of mercury. However, the largest contributor of mercury is likely the reservoir itself (Green and Beck, 1995), which is slowly releasing methyl mercury from flooded sediments.

There does not appear to be any contaminant research conducted on other aquatic life, such as freshwater clams and mussels in the basin. These species are sometimes useful indicators of environmental pollution as they bioaccumulate a wide variety of contaminants such as trace metals, pesticides, and herbicides. Due to their sedentary nature, position in the food chain, longevity, mode of feeding as well as abundant distribution, they are sometimes a better indicator than water quality of environmental impacts of contaminants (Forester, 1981).

2.6 Turbidity and Sedimentation

2.6.1 Description

Soil erosion can cause silt loading and turbidity problems in the receiving streams, rivers and lakes. This can present problems for recreation use of water bodies because of decreased visibility (Fisheries and Oceans, 1992). Sediments are also known to cover fish spawning areas. Sedimentation, the settling out of suspended sediments, can also affect the storage capacity and life span of reservoirs (Kuiper, 1962).

Sediments carried to surface waters by erosion activity are a pathway for nutrients and contaminants to enter the watershed. The creation of ditches greatly increases this problem. Storm runoff from agricultural fields is rich in phosphorus, as sediment bound phosphorus forms a large percentage of phosphorus from cultivated land (Tones, 1987). Particulate phosphorus in aquatic environments can become bioavailable for plant and algae uptake within several hours. Phosphorus loading can lead to algae growth and eutrophication of downstream water bodies such as the Lake of the Prairies in Manitoba (Fisheries and Oceans, 1992; Moenig and Lakatos, 1976).

A study of municipal and irrigation effluent in Alberta indicated that heavy metals such as copper, nickel, zinc, cobalt, iron, cadmium, lead, manganese, chromium, as well as mercury were found in eroded sediments. Further investigation noted that a number of pesticides were also found to be carried by sediment in trace amounts (Ongley, 1981).

Sedimentation can have a profound impact on aquatic environments by altering habitats. A study addressing land uses and their associated impact on aquatic habitat within the basin was not found. However, a study of Dauphin Lake (Government of Manitoba, 1989) points to possible changes facing the aquatic environment of the Upper Assiniboine River Basin. Dauphin Lake has experienced a tremendous amount of nutrient loading and sedimentation to where it has created problems for the fishery. Fish spawning success has dropped with high sediment loads because of changes to the spawning habitat. Fish spawning substrates have been covered with silt, suffocating incubating fish eggs. Phosphorus loading, primarily from agricultural activities, has lead to eutrophication of the lake and to summer fish kills. Channelization of drainage ditches also increased soil erosion and the destruction of natural spawning habitat (Government of Manitoba, 1989).

According to another study on walleye in the Dauphin Lake watershed, sedimentation of streams due to drainage activities dramatically decreased the survival rate of eggs (Gaboury, 1985). Reduced visibility due to suspended particulates can also interfere with fish feeding such as with northern pike which relies on sight to capture prey. Suspended sediment screens out sunlight, and ultimately lowers the traditional sources of food supply due to reductions or changes in aquatic vegetation (Fisheries and Oceans, 1992). CCME (1987) guidelines indicate that turbidity should not be increased more than 5.0 NTU (Nephelometric Turbidity Units) over conditions of natural turbidity of less than 50 NTU. Also, to protect aquatic life, total suspended solids should not increase beyond 10 percent of background levels (CCME, 1995).

2.6.2 Status and Trends

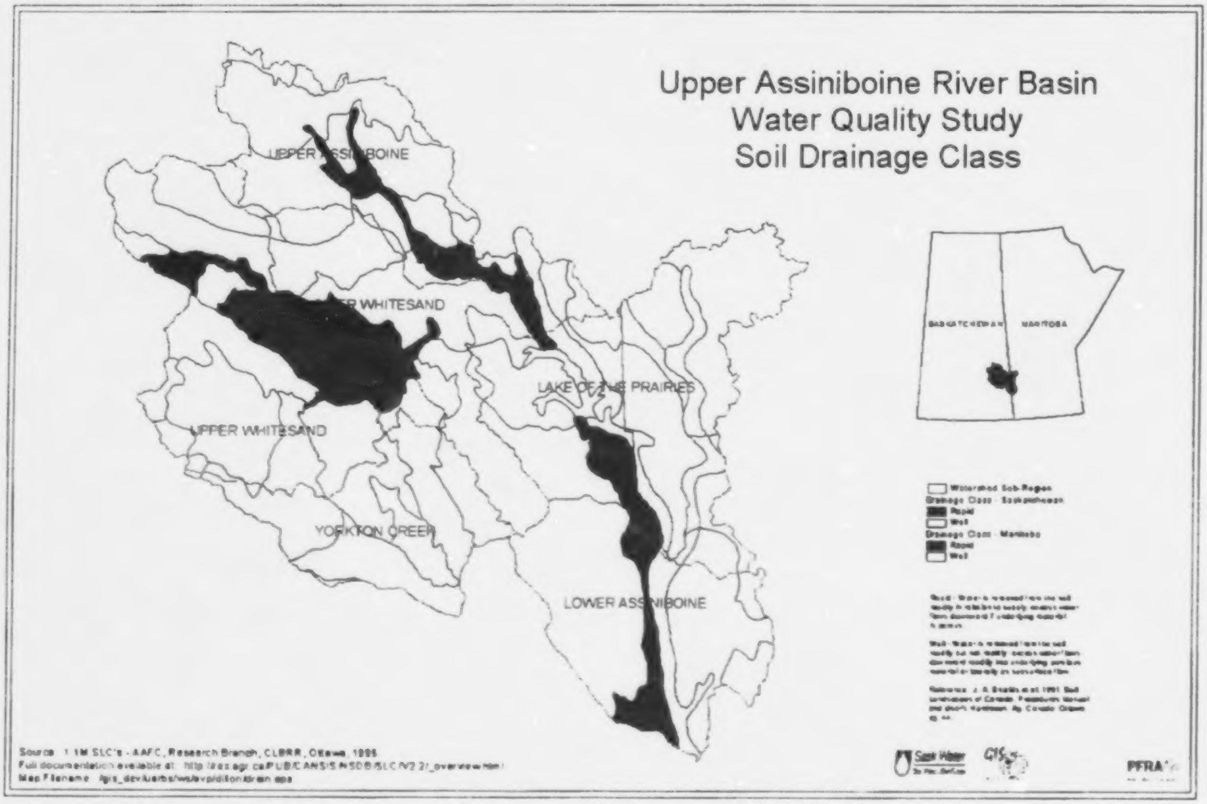
Figures 6 and 7 display soil drainage classes and soil erosion risk, respectively, for the Basin. Erosion vulnerability mapping by Agriculture Canada (1990) for the Upper Assiniboine Basin indicates that portions of the basin are at high risk for wind and/or water erosion. The maps were developed based on soil characteristics, topography, climate, cropping techniques and areas under cultivation. Areas at high risk for wind erosion in Manitoba occur along the provincial boundary. Risk in Saskatchewan is high at Good Spirit Lake and the area west of Yorkton and Melville. The upper reaches of the Assiniboine River in the Sturgis area is also ranked as high risk, with potential for severe erosion occurring just downstream of Sturgis.

The erosion vulnerability mapping (Agriculture Canada, 1990) also indicated that the risk of water erosion was low for most of Saskatchewan, except for the upper reaches of the Assiniboine River where risk was considered to be medium to high. In Manitoba, water erosion risk was ranked as severe in the area extending from the upper reaches of Big Boggy Creek and the Shell River to the Shellmouth Dam. In the vicinity of Russell there is medium risk. The mapping indicated that 50 to 80 percent of the basin in Saskatchewan and upwards of 80 percent in Manitoba was cultivated. In all areas, use of soil erosion conservation methods was considered to be below 40 percent of the total land base.

In the Upper Assiniboine River Basin, only one published study of sediments was found (Ashmore, 1990). The sample sites were located at Kamsack and Russell. Sediment levels were very high during periods of spring runoff at both stations and were believed to have originated in cultivated fields adjacent to the Assiniboine River. Due to low sediment loads at Russell as compared to Kamsack, it is believed that the Lake of the Prairies Reservoir is trapping sediment. This serves to slightly reduce its flood control and water storage capacity. The Theodore Dam upstream of Kamsack is also believed to be trapping significant quantities of sediment (Ashmore, 1990).

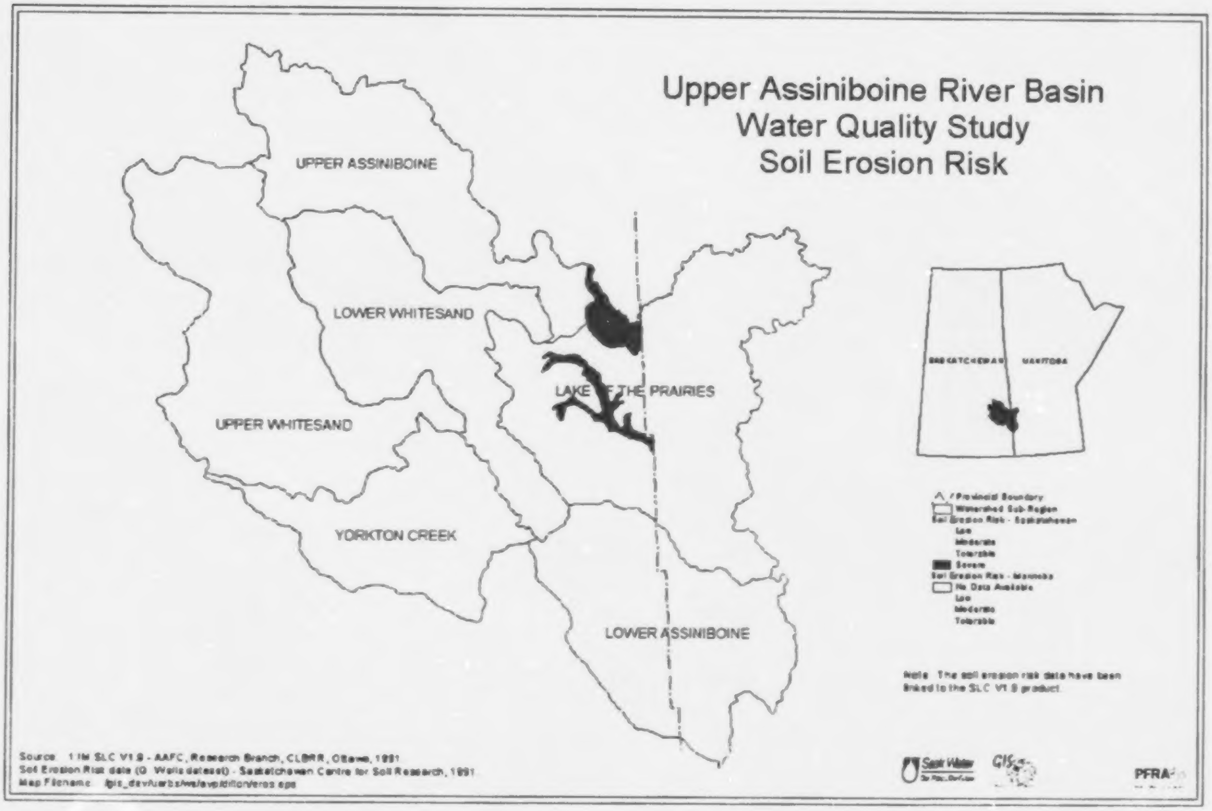
In general, silt loading of watersheds in the Canadian Prairies has been less than recent modelling studies anticipated. There are numerous reasons given for this, including lack of data on rates of erosion (Tyrchniewicz and Wilson, 1994) incorrectly modelled rates of erosion (Lerohl and van Kooten, 1995), problems with measuring siltation, or silt captured in a reservoir before reaching the water quality station (Harker, 1997). As Ashmore (1990) has indicated, this phenomenon has been noted in the sediment data obtained downstream of the Shellmouth Dam site. However, sedimentation is still a concern for the basin. The high rate of sedimentation documented in the Dauphin Lake watershed is one of the few examples that provides some indication of the high levels of eroded sediment that can make its way into prairie river systems from human agricultural activities (Fisheries and Oceans, 1992; Government of Manitoba, 1989).

Figure 6 Soil Drainage Classes


Upper Assiniboine River Basin
Water Quality Study
Soil Drainage Class
UPPER ASSINIBOINE
WHITESAND
UPPER WHITESAND
LAKE OF THE PRAIRIES
YORKTON CREEK
LOWER ASSINIBOINE
SASKATCHEWAN
MANITOBA
Watershed Sub-Region
Drainage Class - Saskatchewan
Rapid
Well
Drainage Class - Manitoba
Rapid
Well
PFRA

Source: 1:1M SLC's - AAFC, Research Branch, CLBRR, Ottawa, 1995
Full documentation available at: http://res.agr.ca/PUB/CANSIS/NSDB/SLC/V2.2/_overview.html
Map Filename: /gis_dev/users/ws/avp/dillon/drain.apr

Figure 7 Soil Erosion Risk


Upper Assiniboine River Basin
Water Quality Study
Soil Erosion Risk
UPPER ASSINIBOINE
LOWER WHITESAND
LAKE OF THE PRAIRIES
UPPER WHITESAND
YORKTON CREEK
LOWER ASSINIBOINE
SASKATCHEWAN
MANITOBA
/ Provincial Boundary
Watershed Sub-Region
Soil Erosion Risk - Saskatchewan
Low
Moderate
Tolerable
Severe
Soil Erosion Risk - Manitoba
No Data Available
Low
Moderate
Tolerable
Sask Water
GIS
PFRA

Note: The soil erosion risk data have been linked to the SLC V1.0 product.

Source: 1:1M SLC V1.0 - AAFC, Research Branch, CLBRR, Ottawa, 1991
Soil Erosion Risk data (G. Wells dataset) - Saskatchewan Centre for Soil Research, 1991
Map Filename: [illegible]

2.7 Pathogens

2.7.1 Description

Pathogens are disease producing microorganisms (Coilocott and Dobson, 1974) such as bacteria, viruses, protozoa, and helminths. Water contaminated with pathogens can impact livestock health, reduce growth and vitality, limiting milk production for cattle and make animals more susceptible to disease. Some pathogens can also be transmitted between species via water, such as infectious bursitis and Newcastle disease in poultry (CCME, 1987). Newcastle disease can spread between shorebirds and domestic poultry, causing paralysis, breathing problems and death (Manitoba Environment, 1993). Humans can also be affected by pathogens with health impacts that can range from mild to severe (Kowal, 1985). The virus causing Newcastle disease in birds for example, can also infect humans causing temporary inflammation of the eye and eyelid. However, pathogens of greater concern are those that are persistent in aquatic and soil environments such as *Salmonella*, *Ascaris*, *Taenia* and *Giardia lamblia* (Bircham and Bruneau, 1985). These pathogens can be transmitted from animals and humans via media like manure, which allow the organism to enter water supplies.

Soil characteristics can affect the survival rates of pathogens in manure, deposited by livestock, or spread on agricultural land as municipal sludge (Kowal 1985, EPA 1976). For example, moist soils tend to increase the survival time of some pathogens. In sandier soils, which do not hold moisture as long as those high in organic material, survival time is decreased. However, coarser sandy soils are more permeable and likely allow pathogens to percolate down through the subsurface. Acid soils (pH 3-5) are less hospitable environments for pathogens than soils with more neutral pH levels (Hermanson and Thomason, 1992; EPA, 1976). Colder temperatures can also increase survival rates while sunlight will decrease lifespan. The presence of soil microorganisms which prey on pathogens will negatively affect survival rates (Kowal, 1985).

The form of the waste at the time of application influences the number of viruses, bacteria such as coliforms and other pathogens present. Dewatering sludge before application decreases virus survival rates. Impervious soils, sloped topography and physical qualities can allow runoff carrying pathogens to enter watercourses directly. In addition, some soil microbes have the ability to decompose pathogens over time. Opportunities for pathogens to affect ground water depend on the permeability and other qualities of the soil, the location of ground water to the surface, the characteristics of the pathogen itself and the climatic conditions (Hermanson and Thomason, 1992; EPA, 1976).

Acceptable application rates for sludge and liquid effluent are not based on possible pathogen contamination of ground and surface water. Guidelines for both Manitoba and Saskatchewan recommend that annual application rates should be based on nitrate nitrogen soil levels that do not exceed 100 kg/ha on medium to heavy textured soils and 80 kg/ha on light textures soils (Manitoba Agriculture, 1994; Saskatchewan Agriculture and Food, 1997a).

Fecal coliform, the bacteria originating in the intestines of livestock, humans, and warm-blooded wildlife, are used as indicators for the presence of pathogens as their presence in water indicates fecal contamination. Fecal coliforms may not necessarily cause illness themselves, but when present in significantly large numbers, are often associated with other disease causing organisms (CCME, 1987). No single microorganism is considered to be an appropriate universal indicator of pathogen contamination. Fecal coliforms, the indicator presently used, have a greater die-off rate than protozoa and viruses and are more sensitive to treatment processes (CCME, 1987; Environment Canada, 1985).

Guidelines for total coliform organisms for drinking water are no more than 10 per 100 ml and none of those detected should be fecal coliforms (those from warm-blooded animals) (Appendix 1). There are also guidelines for recreation areas; over five tests in a 30-day period, there should be less than 200 fecal coliforms per 100 ml for activities coming in contact with water and 1000 fecal coliforms per 100 ml for activities with little contact (CCME, 1987; SERM, 1997; Williamson, 1988a). No guidelines have been developed for livestock watering, although it is recognized that animal health can be impaired by drinking from contaminated supplies (Buchanan, et. al., 1996).

2.7.2 Status and Trends

Green (1996) found that waterbodies receiving runoff from hog manure applied to snow covered fields were below the Manitoba recreation objective of 200 fecal coliform per 100 ml (Williamson, 1988a). This was also confirmed by Beck (1996) in a Manitoba study on cattle manure that found coliform rates in the receiving streams also to be below the recreation guideline. However, it should be noted that coliform levels in the runoff itself were many times greater and the guideline was only achieved because of dilution.

A four-year study of bacteriological characteristics at Manitoba recreational beaches (Williamson, 1988a) found the fecal and total coliform bacteria level at the Asessippi Park beach to be within the surface water quality objectives for primary recreation activities.

3.0 ACTIVITIES OF CONCERN

3.1 Introduction

The main focus of this section of the report is to identify water quality impacts from the following three types of activities in the basin:

- Drainage and surface runoff, within the context of cultivation.
- Rangeland and livestock activities.
- Municipal lagoons, septic tanks, and contaminated sites.

3.2 Cropping

3.2.1 General

There are essentially four activities associated with modern cropping that have the potential to impact water quality. These include crop fertilization, pesticide applications, cultivation techniques, and ditching to improve the drainage of sloughs and wetlands in order to increase available land for cultivation.

These activities are a primary source of what is generally referred to as nonpoint source pollution, which impacts on both surface and ground waters in the basin. While pollutants emanating from an individual farm may be minimal, the cumulative effect of farm activities in a region may have significant implications for receiving waterbodies. Due to the variety of sources, nonpoint source pollution is very difficult to characterize and measure. Occasionally, individual farms can contribute significant levels of contaminants to local ground or surface waters.

The following section provides a general description of activities related to crop farming that are pertinent to the water quality of the Upper Assiniboine Basin. These activities include fertilizer applications, pesticide applications, tillage methods, drainage works and irrigation methods. This section also provides a general description of possible impacts from cropping, field runoff, and drainage activities.

3.2.2 Fertilizer Application

3.2.2.1 Description

Fertilizing is described as adding nutrients to facilitate plant growth (Green et al., 1995). There are 16 nutrients essential for plants, but only three are required in large amounts: nitrogen, phosphorus, and potassium. Use and application is regulated under the Pesticide and Fertilizer Control Act in Manitoba and is similarly regulated in Saskatchewan. Licences are required for the application of pesticides and fertilizers on public property, but are not required for producers applying fertilizers to their personal property.

Fertilizers are generally applied in one of three forms: granular, liquid, or gaseous form (Green et al., 1995). Granular fertilizer is generally applied prior to or during seeding in the spring, or after harvest in the fall. Liquid fertilizer is usually limited to spring applications. Granular fertilizer can be applied by surface broadcasting then incorporating it into the soil at various depths, depending on the equipment being used. Both liquid and granular forms can also be "deep banded," which involves placing the fertilizer in narrow bands, three to four inches into the soil by an air seeder or other equipment. Only nitrogen, in the anhydrous ammonia state, is applied in gaseous form through deep banding (injection) into the soil in the spring (Green et al., 1995). However, if soil conditions are very moist, some producers fertilize with anhydrous ammonia in the fall (Abrametz pers. comm., 1997).

In general, the most effective applications of fertilizer to maximize nutrient uptake by plants are deep banding, followed by deep incorporation in the spring. The least effective is surface incorporation and fall applications (Green et al., 1995). The rationale for fertilizing in the fall is to reduce spring workload (Abrametz pers. comm., 1997). However, there may be 10 to 15 percent loss over the winter months (Campbell, pers. comm., 1998).

Manure spreading, another form of fertilizer, has been a long standing practice in the basin. Adding manure to agricultural land has numerous benefits including providing an on farm livestock waste disposal solution, recycling nutrients locally, and improving the organic content of soils. Most guidelines recommend that manure be spread when it can provide the greatest benefits to the receiving crops, generally during the early growth cycle. The guidelines strongly recommend that manure spreading be avoided in the fall when much of the nutrients will be lost to spring runoff, leaching, or volatilization (Agriculture Guidelines Development Committee, 1994). However, under the Agricultural Operations Act of Saskatchewan, fall spreading is acceptable, particularly if immediate incorporation or injection is practiced. Spreading manure on snow is not recommended due to the significant nutrient losses through volatilization and spring runoff (Green, 1996). Losses due to runoff are very dependent on topography, soil surface, fall moisture content, and the rate of the thaw. Under the new Livestock Waste Regulation developed in Manitoba, winter applications of manure are prohibited (McLeod, 1996). A number of other conditions related to the application of manure have also been included in the regulation.

To maximize benefits and minimize costs to the producer from both chemical and manure fertilization, it is recommended that application rates be based on required nutrient levels and crop uptake rates (Green et al., 1995). If application exceeds uptake, then excess fertilizer is left in the ground. Fertilizing rates are derived by subtracting available nutrients already in the soil from that which the specific crop requires. In Saskatchewan, the government produces a list of recommended fertilizer applications for specific soil types and locations based on the results of regional soil testing programs from the previous year (Abrametz, pers. comm., 1997).

There is little benefit to the producer to over fertilize. Doing so increases production costs in terms of wasted chemicals and increased application time and machinery costs (Green et al., 1995). Nitrogen, not phosphorus or potassium, is usually considered to be the limiting factor in plant growth and thus fertilizer rates are calculated to provide crop nitrogen requirements (Saskatchewan Agriculture and Food, 1997b). Excess nitrogen fertilizer will either runoff, leach, volatilize, immobilize, or denitrify. Runoff may carry excess nitrogen to water bodies; leaching may carry nitrate-nitrogen into the subsurface and possibly into shallow aquifers. Volatilization is the loss of ammonia gas to the atmosphere. Immobilization is a process by which inorganic nitrogen is converted to organic nitrogen, which is a form not available to plants. Denitrification is the biological or chemical reduction of nitrate or nitrite to ammonia gases (Saskatchewan Agriculture and Food, 1997b).

The general recommendation for all producers is that nitrate accumulation in the top 60 cm of the soil horizon does not exceed 88 pounds/acre (16.15 kg/ha) in medium to heavy textured soils and 70 pounds/acre in lighter textured soils. Nitrates accumulated between 0 to 1.2 m should not exceed 144 pounds/acre (26.43 kg/ha) and those below 1.2 to 3.6 m should not exceed 20 pounds/acre (3.67 kg/ha) in each 30 cm increment. Both provinces require large livestock operations to obtain sufficient land to spread manure at rates that do not pose a threat to surface and ground water sources (Saskatchewan Agriculture and Food, 1997a). Any livestock operation requiring approval under the Saskatchewan Agricultural Operations Act must show that they have enough land to spread manure at sustainable rates.

Although not mandatory, Saskatchewan recommends that producers keep records on manure and other fertilizer applications. These records should document application rates, nutrient analysis of applied manure, fertilizer product information, soil tests, environmental conditions at the time of sampling, and the location of applications (Saskatchewan Agriculture and Food, 1997b; Agriculture Guidelines Development Committee, 1995). In Manitoba, producers must file manure management plans, beginning in 1999 (McLeod, 1996).

3.2.2.2 Assessment

Fertilizing practices may impact both surface and ground waters. Fertilizer containing the nutrients nitrogen, phosphorus, and/or potassium, may enter surface water bodies directly through runoff or accidental spillage. Of the three, potassium has the least impact on water quality and is not highlighted as a prime concern in the literature (CCME, 1987; Gregor and Chacko, 1987; Vollenweider and Dillon, 1974; Osei, et. al., 1994). However, nutrient loading from nitrogen and phosphorus may result in eutrophication and/or toxic algae production (CCME, 1987; Vollenweider and Dillon, 1974). Phosphorus, more than nitrogen, is generally considered to be the limiting factor for algae blooms (Bircham and Bruneau, 1985; Osei, et. al., 1994).

Nitrogen will readily leach through the soil structure as nitrate and nitrite and contaminate drinking and livestock watering wells. Due to anaerobic conditions in deep aquifers, there is little opportunity for the nitrogen to degrade or dissipate through volatilization (EPA, 1976).

Phosphorus contamination of ground water is highly unlikely. Due to its chemical nature, phosphorus is basically insoluble and cannot percolate through soil layers. Unless runoff directly enters the subsurface, phosphorus does not present a threat to ground water quality (Tones, 1987).

3.2.3 Pesticide Application

3.2.3.1 Description

Growing demand for food products on a global basis has encouraged chemical inputs in agriculture production to maintain consistently high yields. However, because of the potential for negative long-term environmental impacts, including those on humans, these chemicals are regulated by both provincial and federal governments (Honeycutt and Schabacker, 1991).

Each year, both Manitoba and Saskatchewan prepare crop protection guidelines, which outline the characteristics, application and use restrictions of various approved pesticides. The Pest Control Products Acts of Canada and Saskatchewan require that chemicals not be used in a manner other than as stated on the label. Use and application is also similarly regulated under the Pesticide and Fertilizer Control Act in Manitoba. In Manitoba, any pesticides not recommended by Manitoba Agriculture must have the approval of the Environmental Control Branch of Manitoba Environment (Manitoba Agriculture, 1997). Saskatchewan has similar regulations (see Pesticide Prohibition Regulations).

Pesticide application normally occurs with a surface or aerial sprayer (Saskatchewan Agriculture and Food, 1997a). Pesticide treated seeds are also available for specific crops such as canola (Abrametz, pers. comm., 1997).

There are two general types of herbicides; pre- and post-emergent. Pre-emergent herbicides are applied prior to crop growth and are often supplied in a granular form that is cultivated into the soil. Post-emergent herbicides are applied in a solution form, usually when crops have reached the three-leaf stage. Commonly applied herbicides in the basin are listed in Appendix 3.

Both Manitoba and Saskatchewan have strict guidelines for pesticide container disposal, including rigorous rinsing requirements, puncturing of rinsed containers to render them non-reusable, and disposal at designated sites (Manitoba Agriculture, 1997; Saskatchewan Agriculture and Food, 1997a).

3.2.3.2 Assessment

Pesticides can move through the environment by both direct and indirect mechanisms. Field losses occur during snow-melt or storm surface runoff, atmospheric transport, and subsurface leaching. It has been shown that pesticides are readily transferred from agricultural fields to surface waters via runoff and eroded soils (Ongley, 1981).

The propensity for agricultural chemicals to contaminate surface and ground waters is dependant upon a number of factors, including environmental fate of the chemical, opportunities to reach water sources, and rate of transfer. The chemical characteristics of individual pesticides such as the rate of decomposition, solubility and soil absorption capacity, influences how the pesticide travels and its persistence in the environment. The mode and rate of application primarily influence its ability to contaminate surface and ground water sources. Generally speaking, surface applied chemicals have a greater tendency for runoff, while incorporated chemicals have greater opportunity to leach to subsurface water. Aerial spraying has greater potential than surface spray applications to drift directly onto water bodies. The particular environment in which it is applied also influences the pathway options and environmental fate of the chemical. Micro-climatic conditions such as wind and rain, soil type and chemistry, as well as tillage practices and soil moisture content can affect the movement of pesticides and their persistence (Honeycutt and Schabacker, 1994; Currie and Williamson, 1995).

Surface waters can become contaminated due to improper handling of chemicals. These include over spraying or aerial spray drift, rinsing of equipment too near surface waters, accidental spills, and poor application timing (i.e., prior to rainstorms). Improper handling methods can lead to chemical contamination of both surface and/or ground waters (Environment Canada and PEI Dept. of Environment, 1990).

Ground water contamination occurs when pesticides move through the unsaturated zone and reach ground water before being decomposed by chemical or microbial activity. Downward migration of pesticides primarily occurs with the assistance of water flow referred to as leaching. Heavy rainstorms can contribute to downward leaching (Miller et al., 1992).

Some of the most persistent pesticide products in the aquatic environment are not used to any large degree in the basin (e.g., endosulfan) (Abrametz pers. comm., 1997). The development of genetically altered plant material may ultimately reduce the reliance on farm chemicals (Monenco Consultants Ltd, 1991).

3.2.4 Tillage Methods

3.2.4.1 Description

Conserving soil organic matter is critical to maintaining the production capacity of prairie soils. Various tillage methods for prairie conditions have been developed over the years to conserve soils from erosion and allow the producer to maximize crop yield over the long term while minimizing input expenses.

Conventional tillage is the traditional method of farm tillage used on the Canadian Prairies. Regular and frequent cultivation and summer fallow of fields are used to control weeds and/or conserve moisture. Summer fallow is the practice of not planting once every two or three seasons to allow the land time to rejuvenate. Weed growth is inhibited through regular cultivation. However, disturbed land without vegetation cover or a layer of vegetation residue exposes topsoil to wind and soil erosion (PFRA, 1989).

Conservation tillage systems such as no-till or zero-till reduce soil disturbance and therefore reduce soil erosion loss. These approaches include minimizing cultivation, planting in a narrow seed-bed approximately 2 to 8 cm wide, and managing weed control by using herbicides to maintain a mulch on the soil surface and minimize soil erosion loss (Coutts et al., 1991). While continual cropping is the goal, occasionally a field will be left in chemical fallow. Chemical fallow involves the application of wide spectrum herbicides such as glyphosate to control weed growth rather than regular tillage as is done with summer fallow. Since no tillage occurs and the residual weed matter is left on the surface, soil erosion is inhibited. With conservation tillage, special equipment, such as seed drills or air seeders, is required and herbicide use is greatly increased (PFRA, 1989).

Reduced tillage systems combine no-till and conventional till techniques. Cultivation occurs, but to a far less degree than with a conventional tillage system and chemical fallow is used instead of summer fallow (Monenco Consultants Limited, 1991; Miller, et. al., 1992). Reduced tillage is more common than no-till in the Upper Assiniboine Basin. The reasons why producers favour reduced till over no-till are not clear, but may be a combination of tillage suitability to farming conditions in the area, and a preference for more proven measures. One reason may be the region's high moisture conditions that can produce large amounts of residual straw. The buildup of surface mulch inhibits spring planting. Partially incorporating the mulch facilitates decomposition (Abrametz pers. comm., 1997). However, unlike conventional tillage systems, the residual straw is not fully incorporated, thus leaving some residue on the surface to absorb moisture and limit erosion opportunity. Chemical fallow is also used. Both Conservation and Reduced Tillage systems accommodate continuous cropping which has been recommended for grey and black soils of the Basin to maintain soil organic matter (PFRA, 1989).

There are various other techniques for minimizing unnecessary soil erosion from agricultural fields. Contour farming is used on slopes of more than 8 percent and requires tilling and cropping across slopes to create a ridged surface to capture soil and water. Strip cropping is a similar concept. It relies on planting strips of erosion prone crops, with less erosion prone forages, at right angles to the prevailing winds to reduce soil erosion and runoff. Grassed waterways or drainage channels are designed to reduce erosion and sediment loading in downstream water bodies. Shelter belts and wind breaks are planted to break wind velocity and thus reduce soil erosion and in the process capture snow to reduce spring runoff (PFRA, 1989).

3.2.4.2 Assessment

Tillage practices influence the rates of erosion, as well as nutrient and pesticide runoff to surface water bodies and the leaching of nitrates, pesticides, and herbicides to ground water.

The type of tillage practice influences the rates of erosion and runoff that transfer sediments, phosphorus, pesticides, and herbicides to surface waters. Erosion rates are affected by a variety of factors, namely vegetative cover, climate, topography, and surface soil type. Individual soil types have different propensities to erode. Very fine sand, silt, and very fine sandy loam all have an extremely high propensity to erode. Fine sand, loamy fine sand loam, clay loam, and sandy or silty clay all have a moderate propensity and organic, clay, silty clay loam, sand, loamy sand and silty clay loam all have a slight to negligible erosion potential (Snell, 1984). Conservation and reduced tillage techniques tend to reduce wind and water erosion potential by maintaining surface cover. Keeping land with highly erodible soils in permanent cover also reduces erosion. In contrast, conventional tillage disturbs the surface soil through regular cultivation. Regular cultivation increases the rate of erosion during periods of runoff, particularly on the clay loam soils of the basin (Grevers and Boehm, 1994). Farms not practicing soil conservation techniques such as shelter belts, contour farming, strip cropping, shelter belts and crop rotation, increase soil erosion opportunities (Bircham and Bruneau, 1985).

Runoff varies with the ability of the surface material (soil and vegetation) to capture and absorb moisture, and the surface slope. The steeper the slope and the less surface absorption, the greater the runoff rate (Honeycutt and Schabacker, 1994). Conservation and reduced tillage programs help to maintain moisture by trapping it in standing stubble and partially incorporated vegetation. Melting snow in particular will be more likely to pond on the surface until it can infiltrate the soil, rather than running off. Conservation and reduced tillage actually help to improve the organic content of soil and thus its ability to hold moisture (Manitoba-North Dakota Zero Tillage Farmers Association). Reduced runoff translates into less nutrient, pesticide, and herbicide loading of surface waters.

The limited use of soil conservation techniques is confirmed in the data presented in 1991 Census of Agriculture, Selected Data for Saskatchewan Rural Municipalities. In 1991, over 75 percent of the Saskatchewan portion of the basin was still using conventional tillage systems, with 50 to 75 percent of farmers still relying on summer fallow. From 10 to 15 percent of total cultivated land was summer fallowed annually. Less than one third of the farmers were employing alternate methods to control soil erosion and few farmers reported planting windbreaks or shelter belts for soil conservation. Percentages were also low for farms reporting grassed waterways, strip cropping, and contour cultivation (Statistics Canada, 1993).

When this information is reviewed in conjunction with the wind and water erosion mapping from Agriculture Canada, it appears that from the late 1970s until the early 1990s, soil conservation methods were not extensively used in the basin. New data will be available shortly from Census Canada and would indicate if soil conservation practices have improved.

While conservation tillage reduces runoff and erosion and thus contamination of surface water, there is evidence to indicate that it may increase the potential for leaching of nitrates and pesticides. The reason is that soils which are not cultivated have greater numbers of macro pores than cultivated soils. Macro pores are defined as pores created by soil fauna, plant roots, integrated cracks and fissures. Since these pores are not disturbed each year as in conventional tillage systems, they can become pathways for surface moisture to more rapidly reach subsurface layers. Essentially there is less opportunity for pesticides and even nutrients to be filtered out in the upper soil layers (Miller, et. al., 1992). Studies have found pesticides in ground water shortly after application under conservation tillage regimes, particularly following a rain storm. These concentrations remained one to two orders of magnitude below drinking water guidelines. Nitrates displayed similar patterns of contamination (Steenhuis, 1985).

In addition, conservation tillage demands a greater reliance on herbicides to control weed growth and thereby greater amounts are applied over time. While rates of erosion are lowered and thus opportunities for sediment and phosphorus loading of water bodies are reduced, higher rates of herbicide application may translate into increased herbicide loading of surface water bodies and ground water aquifers. Conservation tillage shifts chemical usage from incorporated herbicides like trifluralin, to surface applied herbicides like glyphosate (Roundup) and 2,4-D. Studies in Alberta have shown that 2,4-D, in particular, has a great propensity to leach, unlike glyphosate and trifluralin (Hill and Harker, 1996). In another Alberta study, the herbicide triallate was shown to have a greater risk of leaching in conservation versus conventional tillage systems (Miller, et. al., 1992).

The tendency for a chemical to leach is highly dependant on its ability to bind with the soil structure and its persistence over time. The greater its ability to bind with the soil, (lower rates of water solubility) and the more rapidly it breaks down, the less likely the chemical will leach and contaminate ground water. Ground water contamination risk may increase with conservation tillage because of increased rates of herbicide usage, more direct access to the subsurface and the specific nature of the chemicals applied for conservation tillage regimes (Miller, et. al., 1992). It must be noted however, that studies could not demonstrate increased accumulation of herbicides in conservation till soils. Insufficient research has been done to comment on the infiltration potential of nitrates, herbicides and pesticides with reduced till systems (Miller, et. al., 1995).

3.2.5 Drainage Works

3.2.5.1 Description

Drainage works involve facilitating the removal of water from land, through grading, canals, or pipelines. Historically, drainage activities on the prairies were aimed at bringing more land into production to support settlement of the region (Manitoba Natural Resources, 1985). Drainage activities have continued due to fiscal support directly and indirectly by various government agencies and growing international demand for agricultural products. Drainage has also continued because it is a free economic activity by which users incur very little of the total social cost of drainage. Other than the cost of a licence, which is low in both Manitoba and Saskatchewan, there is minimal cost to individuals for draining fields and wetlands. Until the 1990s, the Grain Transportation Act and Wheat Board Quota system both encouraged drainage activities by providing benefits tied to the amount of land under cultivation (Chambers, 1984).

There has been greater effort in recent years to protect and maintain on-farm potholes and wetland areas as indicated by the North American Waterfowl Protection Agreement. Ducks Unlimited, the Saskatchewan Wetland Corporation, and the Manitoba Habitat Heritage Corporation, have been actively preserving wetland areas and entering into protection agreements with private land owners such as farmers. Education programs which promote the on-farm benefits of potholes, sloughs and wetlands as ground water recharge areas have helped to change attitudes and provide justification for preserving on farm surface water storage areas (Harker, 1997). Both Saskatchewan and Alberta have an easement program to reduce taxes on land for farmers who are willing to put easements on for the purpose of wildlife protection (Campbell, pers. comm., 1997).

In order to construct and operate drainage structures, Manitoba and Saskatchewan farmers are required to obtain licences from Manitoba Water Resources and Sask Water respectively. However, both provinces have many unlicensed drainage structures in the basin and thus it is not clear how much drainage is actually occurring and the impact it is having on the receiving water bodies (ARMAB, 1996; Sask Water, 1995). When interprovincial drainage issues arise, they are addressed through the Prairie Provinces Water Board Master Agreement on Apportionment (PPWB, 1992).

3.2.5.2 Assessment

Drainage is a controversial activity because of its impact on downstream water quality and quantity. Storage of runoff in catchment areas allows sediments to fall out of suspension, pesticides to degrade, and nutrient levels to lower before flowing on larger surface waters. When this storage capacity is removed, runoff is immediately directed to rivers and streams. A study in Saskatchewan found that wetlands significantly reduce phosphorus, nitrogen, BOD, and coliforms. These catchment areas also provide valuable habitat and staging areas for waterfowl and shorebirds (Russell, 1987). In addition, drainage of catchment areas such as marshlands can impact the recharge and discharge of the aquifer and result in ground water quality changes (van der Kamp, 1989).

Ditches can carry water contaminated by high concentrations of salts and other chemicals from the water source (catchment area). Evaporation of the water can further concentrate the mineral content (Allison, 1988; ECA, 1988; ECA, 1982; Boyd, 1975).

Drainage channels are often straight ditches that create accelerated runoff flows that encourage erosion of the drainage ditch itself (Fisheries and Oceans, 1992). Drainage is also criticized as increasing flood duration and length of flood peaks in the receiving water bodies (Sask Water, 1995). Gobert (1983) outlined the potential impact of large scale drainage projects on flood conditions in the basin. With the addition of drainage waters, the duration and peak flows of small floods (1:2 year flood) increase, creating flooded that will last as much as a week longer than under natural conditions. Large floods (1:500 year flood) appear not to be similarly affected. Higher flood levels at longer durations mean more flood plain is inundated, increasing bank erosion which augments suspend sediment loading and the associated nutrient, pesticide, and herbicide loading of the receiving surface waters (Fisheries and Oceans, 1992).

3.2.6 Irrigation Methods

3.2.6.1 Description

Irrigation serves to increase the water content of the soil. It is used in areas where the precipitation characteristics or soil types are not conducive to growing vegetation. In agriculture, it can be important in the production of high value crops, thus diversifying agricultural production and supporting value added processing. Irrigation is also used on golf courses, landscaping, and in recreational areas.

Irrigation application methods include centre pivot, wheel move, and big guns. While centre pivot systems remain fixed in fields, the latter two systems are typically moved from field to field during the dry summer months, to increase the water content of the soil.

In terms of water content, the root zone for most agricultural plants is usually unsaturated. There is a depth at which the soil is saturated and a well installed in the soil will fill up to a certain elevation. This elevation represents the upper surface of the water table. Between the unsaturated zone and the water table is a zone where capillary action carries water upward from the water table, saturating the surrounding soil. The water remains in this zone as a result of surface tension. This zone is known as the capillary fringe or the tension saturated zone (Freeze and Cherry, 1979).

There is very little irrigation occurring in the upper portion of the basin at the present time (Canada West Foundation, 1952). Statistics Canada (1993) indicated that only 451 acres of farmland was being irrigated in the Saskatchewan portion of the upper Assiniboine Basin. The basin receives approximately 400 mm of precipitation per year, which is sufficient for the cereal and forage crops that are presently produced in the area. Supplemental irrigation is not cost effective for these crops. The number of growing days is also not adequate in most years for crops such as corn, which would benefit from supplemental irrigation (Abrametz pers. comm., 1997). The potential for soil salinity in the Yorkton area and northwest of Foam Lake also limits the potential for irrigation development (Eilers, 1988; Eilers, 1987).

3.2.6.2 Assessment

As mentioned previously, irrigation of crops does not occur in the upper portion of the basin to any significant extent. However, if irrigation does become more widespread in this region, increased nitrate, pesticide, herbicides, and sodium leaching rates are likely.

When irrigation water is applied, both the water table beneath and the capillary fringe will rise. If the water table is raised enough, the capillary fringe will enter the root zone of the plants, and the soil will become waterlogged. If enough water is added, the water table itself will intersect the root zone.

There are problems associated with the salts and other minerals that are present in the ground water. When the top of the capillary fringe is near the surface of the soil, evaporation will lead to the deposition of salts near the surface. As water continues to rise through capillary action, more salts will be deposited near the surface, leading to an accumulation of salts in the soil (Hagan and Roberts, 1972). This process is called salinization (OECD, 1991; Allison, 1988; ECA, 1988; Bouwer, 1987; Law, 1987; Henry, 1986; Verma, 1986; Sanderson, 1981; White, 1978).

The importance of the action of the capillary fringe above water tables is related to the type of soil and its ability to retain water. Capillary fringes are typically thin in sandy soils and thick in clay soils (Bouwer, 1987). A further complicating factor is that the buildup of salts in soil increases the ability of the soil to retain water, which thickens the capillary fringe. This is because most salts are hydrophillic and readily attract and retain water.

Proper drainage of irrigated fields and careful application of water can prevent waterlogging and salinization of the soil. Irrigation should be avoided in areas with naturally high water tables and poorly draining soils.

Even where irrigation does not raise the water table sufficiently to cause problems with waterlogging and salinization, the addition of water to the land can lead to pollution of ground water by salts, fertilizers, and pesticides (Sabol et al., 1987; Sonnen et al., 1982; Boyd, 1975). In this case, water percolating through the soil dissolves salts, fertilizers, and pesticides and carries them to the underlying aquifer. This deep percolation of water can take decades to reach the water table; thus, the effects of ground water pollution by irrigation practices often take a long time to show up as a problem (Bouwer, 1987).

A positive impact on ground water due to impoundment involves a gradual recharging of underlying aquifers, as water gradually seeps into the ground water (Hubbard and Linder, 1986).

Ground water pollution resulting from irrigation can be reduced by limiting the application of water to the land and ensuring that there is sufficient drainage. This will reduce the amount of salts leached out of the soil, allow for greater denitrification of fertilizers in the soil, and allow time for the degradation of pesticides applied to the soil.

Hill and Harker (1996) confirmed the occurrence of increased rates of leaching for herbicides at test sites at Lethbridge and Lacombe Alberta. Sodium contamination, arising from irrigation activities, has become a ground water quality concern in the United States (USCATST, 1992). Rates of soil erosion and surface runoff and the associated increased risk of surface water contamination is also higher with irrigation activities. Surface runoff containing pesticides, such as MCPA and 2,4-D, have been recorded (Cessna et al., 1996; Miller et al., 1996). Sodium and a variety of heavy metals have also been noted in runoff under irrigation conditions.

F3

3.2.7 Summary

Cropping, field runoff, and drainage activities involve four main activities that are important for agriculture from a water quality perspective: fertilization, pesticide application, cultivation, and drainage.

Fertilizer application has the potential to introduce nutrients to surface and ground water. This typically occurs when application rates exceed crop uptake rates. Some research indicates that nutrient levels can be higher near areas where fertilizer is used, but high nutrient levels are not attributed solely to this activity. While phosphorus levels in the Assiniboine River basin still often exceed water quality criteria, the decreases in nitrogen levels since 1980 has been attributed to improvements in municipal wastewater treatment technology.

As indicated previously, pesticides are often important in agriculture, to protect from weeds, insects, and fungi. There are guidelines on use, but problems can still occur. Pesticides do not appear to be as big a concern in the prairies as in the United States or in eastern Canada. They have been detected in the prairies, but are generally below acceptable water quality criteria. Some areas of the basin are more susceptible to problems, due to local conditions such as soil type, slope, climate, and depth to ground water.

Tillage methods are used to control weeds, and are thought to increase soil productivity. Potential concern relates to increased erosion and contaminant loading to water. This potential is influenced by aspects such as timing, soil type, and slope. Conservation tillage is a method to minimize erosion. However, more herbicides are typically used over conventional methods and this can increase risks of water contamination.

Drainage involves the grading, construction of ditches to allow more land to be brought into agricultural production. Potential effects include erosion, contaminant transfer, and loss of wildlife habitat. Efforts are being made to maintain wetlands and wooded areas on agricultural lands, in order to maintain wildlife habitat and reduce flood problems.

Irrigation is not used extensively in the basin. Concerns include an increase in soil salinity, erosion, and contaminant transfer to water. Aspects such as timing and soil type influence the potential for impacts.

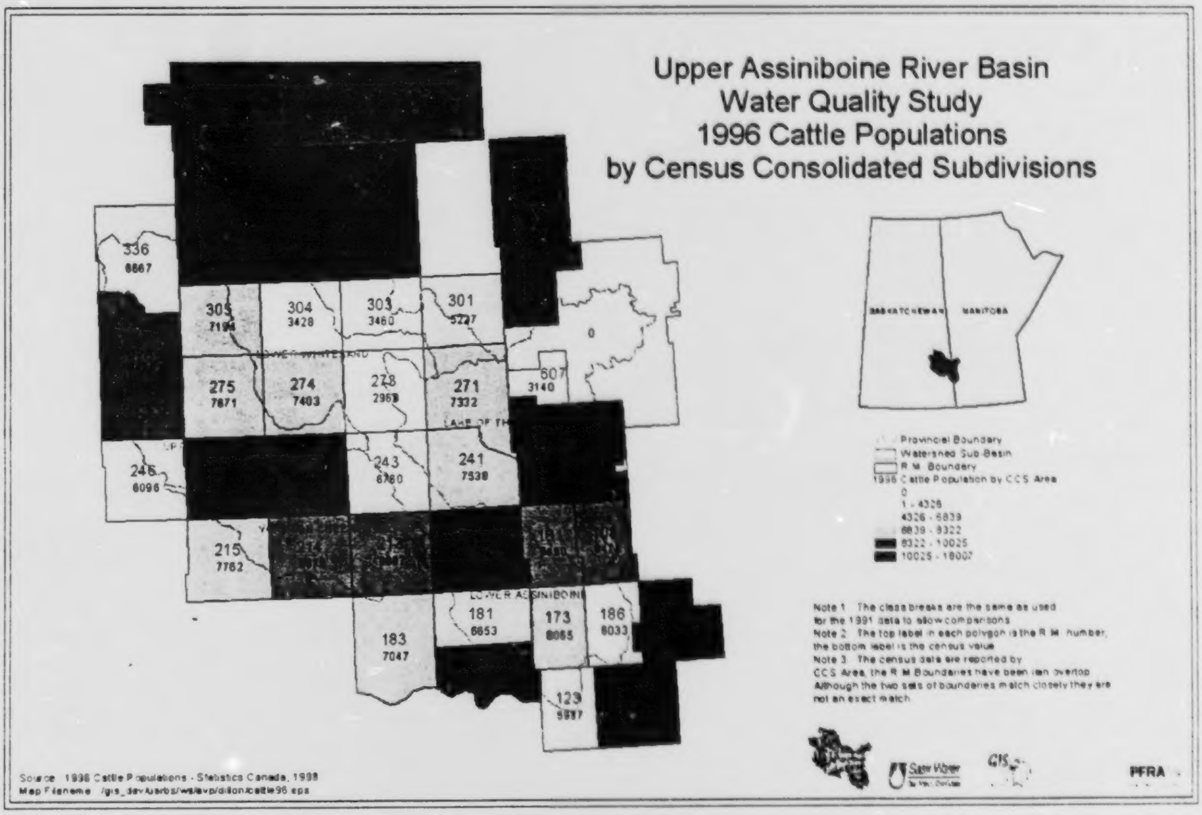
3.3 Livestock and Range Management

3.3.1 General

Livestock operations are an expanding agricultural activity on the Prairies. There is a wide diversity in the kinds of livestock operations in the basin, but large scale cattle, hog and poultry operations are becoming more common. Livestock operations are a source of both point and nonpoint sources of pollution. Figure 8 displays the 1996 cattle populations by R.M. in the basin. There does not appear to be any observable patterns (i.e., areas of concentrated operation, or areas with low activity).

Intensive livestock operations (e.g., feedlots) are regulated for protection of ground water and surface water under various legislation in each province. In Saskatchewan, an intensive livestock producer is required to adhere to the Agricultural Operations Act that addresses protection of ground and surface water through proper storage and management of manure and animal waste. For large operations, applications for approval under the Agricultural Operations Act are also reviewed to ensure compliance with the Environmental Assessment Act. Sask Water requires ground water investigation permits where ground water is the water supply, approval for water use (well and reservoir construction and operation), and for alteration of drainage under the Saskatchewan Water Corporation Act (Saskatchewan Agriculture and Food, 1997a).

Figure 8 1991 Cattle Populations by R.M. in the Basin


336
6667
305
7196
304
3428
303
3460
301
5227
0
607
3140
275
7671
274
7403
278
2969
271
7332
246
6096
243
6760
241
7538
215
7762
181
6653
173
8065
186
8033
183
7047
123
5937
LOWER ASSINIBOINE
LAKE OF THE
SASKATCHEWAN
MANITOBA
Provincial Boundary
Watershed Sub-Basin
R.M. Boundary
1996 Cattle Population by CCS Area
0
1 - 4326
4326 - 6839
6839 - 8322
8322 - 10025
10025 - 18007
Save Water
GIS
PFRA

Upper Assiniboine River Basin
Water Quality Study
1996 Cattle Populations
by Census Consolidated Subdivisions

Note 1 The class breaks are the same as used for the 1991 data to allow comparisons
Note 2 The top label in each polygon is the R.M. number, the bottom label is the census value
Note 3 The census data are reported by CCS Area, the R.M. Boundaries have been lain overtop. Although the two sets of boundaries match closely they are not an exact match.

Source 1996 Cattle Populations - Statistics Canada, 1998
Map Filename /gis_dev/users/ws/avp/dillon/cattle96.eps

In Manitoba, the new Livestock Waste Regulation under the Environment Act describes minimum requirements for the use, management, and storage of livestock waste. Under this regulation, producers who construct, modify, or expand an earthen manure storage are required to obtain a permit. In addition, minimum requirements for storing, composting, transporting, and applying manure to cropland are outlined. The Act stipulates that the designs and activities associated with construction, maintenance, and operation are not to cause pollution of surface water, ground water, or soil. Acceptable distances from surface watercourses, springs, and wells used for domestic purposes are to be maintained. Under the Farm Practices Protection Act, a Review Board will have the power to determine whether farm practices are occurring in an acceptable manner.

The following section provides a general description of activities related to livestock and range management, relevant to the water quality of the Upper Assiniboine Basin. These activities include livestock watering, range management, manure management, and feedlots.

Nutrients, pesticides, sediment, and pathogens impacts on water quality result from range management and livestock watering, as well as the accumulation, storage, and spreading of manure. This section provides a general description of these impacts.

3.3.2 Livestock Watering

3.3.2.1 Description

Traditionally, cattle have been given direct access to watering areas, including manmade dugouts and natural lakes and watercourses. Some farmers overwinter cattle next to rivers and provide water by chopping holes in the ice. However, producers have increasingly been providing livestock watering facilities away from sources. A number of low cost pumping systems are available to the producer that rely on gas, solar, wind, or stream currents for a power source. Products such as the self-priming nose pump for cattle do not require a power source and allow livestock to pump water for themselves (Government of Manitoba, 1995). Producers still providing direct access to surface water sources have been encouraged to limit access to one location through fencing that extends into the creek or slough. Providing an access ramp with a gravel base will minimize bank erosion from trampling (PAMI, undated).

3.3.2.2 Assessment

Watering systems that do not allow cattle direct access to the water source help to protect water quality and livestock health. When large animals such as cattle have direct access to watercourses, a wide variety of impacts can occur. This can range from increased erosion and reduced water quality, not only for downstream areas, but for the animals themselves.

Livestock allowed unrestricted access may destabilize bank slopes and destroy shoreline vegetation and thus increase the potential for erosion and stream sedimentation. The preservation of shoreline vegetation is important because it helps to protect water quality and aquatic habitat by:

- Reducing nutrients levels in runoff. Nutrient loading from nitrogen and phosphorus may lead to algae booms, which can lower water quality by changing quality and taste, as well as reducing available oxygen for fish and invertebrates as it decomposes (USCATST, 1992).
- Filtering out sediments that may destroy fish spawning habitat.
- Reducing pesticides in runoff that may contaminate water supplies.
- Reducing water temperature in summer by shading the shoreline. Cooler water holds more oxygen and reduces the effects of pollution that can be magnified by warmer water conditions (Fisheries and Oceans, 1992).
- Enhancing the edge effect, by increasing feeding opportunities for aquatic life.
- Reducing runoff rates and thus erosion of shorelines (Graham, 1995).

While erosion is not a concern during winter, overwatering cattle near watercourses can create areas of high manure content, which can be washed into the watercourse in the spring.

When livestock have free access to water sources, there is the potential that diseases such as leptospirosis and bovine virus can be more readily spread. This can be deposited either gradually, during the grazing season, or, in the case of overwintering cattle near watercourses, as a large rapid input during the spring melt. Fecal coliform contaminating the livestock watering source via manure also may threaten the health of livestock (Fisheries and Oceans, 1992). Tests by Agriculture Canada in Alberta indicated that poor quality water may affect an animal's weight gain by as much as 23 percent (Friesen, 1994). Research by Agriculture and Agri-Food Canada at Lethbridge have identified a positive correlation between the presence of *Giardia*, a microscopic intestinal parasite that causes diarrhea, and weight loss in cattle. It is also thought that higher levels of silt, manure, and algae in water make it less palatable and livestock tend to drink less. Lower water intake by livestock tends to lower forage consumption (Fisheries and Oceans, 1992).

Harker (1997) cited research indicating that higher levels of nutrients appear to be related to cattle operations, especially where animals are allowed direct access to watercourses. However, it was also noted that impacts appeared to be concentrated at specific sites, for short periods, and are also difficult to separate from wildlife impacts.

3.3.3 Range Management

3.3.3.1 Description

Range management practices focus on maintaining pasture land and quality forage for cattle and other livestock over the long term. Pasture rotation and appropriate stocking densities are commonly used to avoid overgrazing and allow rejuvenation of vegetation (Abouguendia, 1990). Overgrazing reduces yields and increases soil erosion. Another technique is to plant or encourage diverse vegetation rangeland species so that good quality forage is available throughout the season (Abouguendia, 1990). Occasionally forage crops are fertilized to improve productivity and herbicides and pesticides are applied to maintain forage health. The fertilization techniques commonly used are top dressing which is a surface applied liquid or granular fertilizer, or manure spreading (Green and Roberts, 1994; Green, 1995). Pesticide applications depend on the nature of the weed or pest infestation, but are often surface or aerial sprayed (Abouguendia, 1990).

3.3.3.2 Assessment

Good range management practices maintain permanent cover and minimize soil erosion, and therefore help to protect nearby surface water quality. Proper range management techniques such as rotational grazing not only provide benefits to the producer in terms of constant supply of forage, but also positively affects water quality. Overgrazing not only decreases long-term viability of range forages, it exposes soils to erosion from wind and water. Storm runoff carrying sediments from pastures may be rich in phosphorus (Tones, 1987). This erosion also increases sediment loads and siltation of watercourses (Graham, 1995).

If livestock concentration rates are low and cattle are rotated between pastures regularly, there is less opportunity for nutrient contamination of surface and ground waters. Due to low concentrations, animal wastes can be readily absorbed and used by the existing vegetation. Supplemental feeding areas, salt blocks, and watering areas are some of the few potential sources of contamination that can be addressed if proper range management practices are being followed. Livestock trampling around these facilities exposes soil to erosion and these sites become areas of concentrated manure that may leach nitrate and heavy metals to ground water or nutrients to surface water (Tones, 1987). Problems at feeding and salt blocks locations are easily avoided if periodically moved. Water quality issues related to livestock watering were discussed in Section 3.2.2.2.

3.3.4 Manure Management

3.3.4.1 Description

Manure management consists of three primary activities: collection, storage, and disposal. There are three general types of manure systems, as follows:

- Solid manure systems
- Semi-solid manure systems
- Liquid manure systems

Solid manure (contains a solid content greater than 20 percent) systems are used by many feedlots and some barns. Manure, along with straw bedding, accumulates in the confined area until it is cleaned. It is kept dry by providing a well-drained site that slopes away from the feedlot. Solid manure may be piled and stored until it is land-spread during the growing season. Semi-solid manure (contain 5 to 20 percent solids) systems provide limited bedding to confined animals. Using significant volumes of water, semi-solid manure is transferred to long-term storage to dry and is later applied to the field as a solid during the growing season. It is a common practice in dairy, hog and poultry facilities. Liquid manure (contains less than 5 percent solids) is used for confined livestock systems that do not use bedding. It is stored in either a holding tank or earthen manure pond, or is applied directly to the land (Saskatchewan Agriculture and Food, 1997a; Agriculture Guidelines Development Committee, 1995).

Earthen manure storages are regulated under the Agricultural Operations Act in Saskatchewan and Manitoba Environment Act in that province. Holding ponds may be used in solid or semi-solid manure systems to contain and evaporate runoff and liquid manure (Saskatchewan Agriculture and Food, 1997a). Manure is usually spread on agricultural land as it is the most effective means of disposal, in terms of costs and uses of the resource, and is a means of recycling nutrients (Agriculture Guidelines Development Committee, 1995).

Animal manure has long been viewed as a valuable agricultural soil additive; improving nutrient content, as well as soil tilth, structure, aeration, and moisture-holding capacity due to the addition of organic matter (Green, et. al.., 1995; Jacobs, 1994; Agriculture Guidelines Development Committee, 1995). Manure contains nitrogen, phosphorus, and potassium and these elements are readily accessible to plants if in an inorganic state such as ammonium, nitrate, or potassium. However, if nitrogen is bound organically to the soil, it must undergo a process of mineralization by which microbial decomposition releases the nutrients in a form available to plants. It should be noted that a portion of the nitrogen in manure will not be available in the first year of application, but will become available in subsequent years as organically bound nitrogen is mineralized (Green et al., 1995).

The actual nutrient content of manure varies depending upon livestock source and form (liquid or solid). Nutrient content also changes over time, as nitrogen is lost to volatilization, leaching, and/or surface runoff. To maximize the benefits of manure, it is recommended that it be applied only in those amounts that will satisfy crop requirements (Green et al., 1995; Agriculture Guidelines Development Committee, 1995). Excess nitrogen will be lost to volatilization or leaching. Use of manure is most successful when it is incorporated into the soil immediately after application and applied during the growth cycle when plants require added nutrients (Ewanek, 1992).

There are a variety of manure storage options available to the producer, depending upon the operation size and type as well as land disposal program. Manure may be stockpiled once removed from a barn or feedlot until needed during the growing season. Holding ponds may be used to contain runoff from feedlots, relying on evaporation for disposal. Liquid manure can be stored in tanks or earthen manure storages until it is applied to agricultural land (Saskatchewan Agriculture and Food, 1997a).

3.3.4.2 Assessment

There are many opportunities for contaminants to impact surface and ground water quality from manure storage areas, feedlots and field spread manure. These activities influence how pathogens and nutrients have access to water sources. Manure storage may contaminate ground and surface waters if an overflow or break occurs (Hermanson and Thomason, 1992).

Earthen manure storages used for large-scale livestock operations are a common storage mechanism approved by the environment and agriculture departments of both provinces. Some of the common problems experienced with earthen manure storages have been leaking berms, and structurally unstable embankments. In addition, earthen manure storages developed on flood plains, sandy soils, high water tables, with insufficient compaction and backfill around influent lines and leaking discharge lines, allow waste to escape. Over time, this may lead to the contamination of surface and ground waters (Hodgkinson, 1996). Cattle manure has been found to provide a better seal for earthen storage than hog manure (Hermanson and Thomason, 1992). However, in general, all manures have similar potentials to contaminate surface and ground waters with nitrogen, ammonia, phosphorus, and pathogens (Beck, 1996).

Studies of hog manure storages by Maulé and Fonstad (1997) found potassium, nitrates and chlorides seeping 1.5 to 1.8 m in sandy soils, and 0.2 to 0.4 m in clay soils, over a seven-year period. Sandy soils were found to develop a contaminant plume from the storage area. This would suggest that the greater the *in situ* soil permeability, the greater the distance from ground water the lagoon should be located (Fonstad and Maulé, 1997). Also of note, is that nitrate levels in the seepage actually increased beyond those originally tested in the manure, likely due to the microbial conversations of ammonia within the soil column. Phosphorus levels did not increase with the exception of the uppermost layers, largely attributed to soil fixation (Maulé and Fonstad, 1997).

The study also confirmed that fresh manure acts as a seal for earthen storages, decreasing the hydraulic conductivity (seepage rate) between one to three orders of magnitude (Fonstad and Maulé, 1997). However, although the soil appeared to seal, high levels of ions were measured near the lagoon. After the manure was removed and the storage facilities allowed to dry, a return to the original or greater hydraulic conductivity was noted (Fonstad and Maulé, 1997). Seepage was determined to be greater from the sides of the manure storage rather than through the bottom. It is believed that periodic drying and frost/thaw conditions that the sides were regularly exposed to, increased the hydraulic conductivity.

The study by Green (1996) in the Interlake Region of Manitoba examined the effects of hog manure applications on water quality during spring runoff. Target sites had manure applied in February on winter snow and for controlled sites, no manure was applied. Fecal coliform, nitrogen, ammonia and phosphorus levels were measured from water samples taken from drainage ditches and receiving streams and rivers. In general, fecal coliform levels were well below the national and provincial objective limit of 200 organisms/100 ml (CCME, 1987; SERM, 1997; Williamson, 1988a). Nutrient concentrations however, were much higher near test sites than control sites, with phosphorus values registering approximately 350 times greater. Ammonia and nitrogen levels were also high in the receiving drainage ditches. There was no indication that runoff from the study fields caused statistically significant increases in pH, conductivity, biological oxygen demand, total suspended solids, or total dissolved solids (such as calcium, potassium, sodium, chloride, or sulphate) in the receiving rivers. However, testing immediately downstream of the target sites registered higher levels of the above than downstream of controlled sites (Green, 1996).

Spring and summer is best time to apply fertilizer and manure additives, as plant material will uptake the nutrients while a fall application tends to lead to leaching of nitrates, particularly on coarse sandy soils. Spring runoff rates of nitrogen and phosphorus may also be elevated with fall applications. Slopes greater than 6 percent with solid wastes and 3 percent with liquid manure, tend to increase runoff rates of nutrients. Areas subject to flooding, unless soil injected, also experience high rates of runoff and nutrient leaching (Jacobs, 1994). Immediate incorporation of manure into soil helps to avoid surface runoff (Hermanson and Thomason, 1992).

Excessive manure spreading can lead to nitrate leaching and buildup of phosphorus in the upper layers, increasing the risk of surface water contamination from runoff and erosion (Jacobs, 1994). An Alberta study on manure leaching on soil conditions similar to the basin (Chang and Entz, 1996), found nitrate concentrations at one to three times the recommended rate when manure was applied. Minimal leaching was observed below 1.5 m, except during years of high precipitation, when leaching rates were similar to that of irrigated fields.

Pathogen transfer to watercourses can occur when manure is spread on agricultural fields. Pathogen survival in soil ranges from a few days to a several months depending upon the organism, site characteristics and application. For example, protozoa can survive for long periods in water environments, and parasites such as flukes and tapeworms, have eggs and larvae that will live for long periods, occasionally up to years, in soils (Kowal, 1985; EPA, 1976).

Soil characteristics can affect the survival rates of pathogens (Kowal 1985, EPA 1976). For example, moist soils will increase survival time, thus survival time is decreased in sandier soils which do not hold moisture as long as those high in organic material. However, coarser sandy soils are more permeable and likely to allow pathogens to percolate down through the subsurface. Colder temperatures can also increase survival rates, while sunlight can decrease lifespan. The presence of soil microorganisms which prey on pathogens will negatively affect survival rates. Acid soils (pH 3-5) are less hospitable environments for pathogens than soils with more neutral pH levels (Kowal, 1985).

The form of the waste at the time of application tends to influence the number of viruses, coliforms, and other pathogens present. Dewatering waste before application decreases virus rates. Impervious soils, sloped topography and physical qualities will allow runoff carrying pathogens to enter watercourses directly. Opportunities for pathogens to affect ground water depend on the permeability and other qualities of the soil, the depth of ground water, the characteristics of the pathogen itself and the climatic conditions. In general, soil microbes will decompose pathogens over time (Hermanson and Thomason, 1992; EPA, 1976).

3.3.5 Feedlots

3.3.5.1 Description

Feedlots or stock yards are confined pens or barns where livestock are kept for long periods at high densities. Feedlots generally require specialized handling of manure wastes due to the large concentration of animals such as those described above. They also require special site design to channel drainage and orient snow drifts to minimize seasonal runoff through the feedlot or manure storage area (Lakshman, 1982).

3.3.5.2 Assessment

Animal feeding operations can affect both surface and ground water. Contaminants emanating from feedlots include nitrogen compounds, phosphates, bacteria and pathogens, chlorides and occasionally heavy metals (Canter, 1987). The quantity of manure generated will depend on the type of animals and the total animal population within the confined area.

The amount of surface runoff that occurs depends in part on site layout in relation to snow accumulation and drainage patterns. In general, feedlots produce much more concentrated runoff, in terms of phosphorus, than spread manure (Tones, 1987). In feedlots, manure is concentrated in piles, is retained longer and drains away from the site. In contrast, the nutrients in spread manure have greater opportunity to be incorporated into the soil (Lakshman, 1982). Only manure spread on winter snow will produce greater nutrient runoff loads (Green, 1996). Impacts to surface water can also be accentuated if runoff, such as that from spring snow melt, drains through manure storage areas and corrals. Lakshman (1982) found that 72 to 93 percent of phosphorus in runoff from manure is already in a soluble state and available for immediate uptake by aquatic vegetation. This impact is enhanced if there is no vegetation to catch nutrients and eroded soils before entering water bodies (Hermanson and Thomason, 1992).

Another practice that also leads to surface water contamination is wintering cattle in low-lying areas where they are sheltered from the wind These areas are often subject to flooding in the spring (Beck, 1996).

Susceptibility to ground water contamination is a function of animal density, frequency of manure removal, surface treatment/ soil characteristics, and climate (Canter, 1987). In general, ground water below these feedlots has a higher risk of nitrate contamination (Tones, 1987), but different management approaches can reduce leaching. Unpaved feedlots, for example, may over time experience a reduced nitrate leaching rate due to a compacted manure seal that forms on the soil surface. If the seal is disturbed during cleaning, then leaching rates will again return to original levels (Hermanson and Thomason, 1992).

3.3.6 Summary

Several livestock and range management activities, relating to cattle, hog, and poultry are expanding in the basin. Several have presented recent challenges to regulate.

Livestock watering presents the potential for erosion at watering sites, and the introduction of contaminants such as nutrients and pathogens associated with manure. These issues are also a concern for range management. In addition, forage crops are sometimes fertilized, which has impacts previously discussed. Good management techniques, such as careful monitoring and rotating the use of grazing sites and watering areas, can minimize this concern.

Feedlots and manure management involve more intensive livestock operations. Waste materials are typically held in earthen manure storages and/or applied to land. Problems with increased nutrients, pathogens, and heavy metals have the potential to occur, to both surface and ground water. The degree of impact is related to animal density, frequency of manure removal, treatment method, soil types, and climate.

3.4 Municipal Lagoons, Contaminated Sites, and Septic Systems

3.4.1 General

Larger urban centres, communities, and farms in the basin rely on lagoons to treat waste materials. Smaller communities and individual farms sometimes use septic systems. Both systems have implications for surface and ground water quality. In addition, there are a number of landfills, chemical storage sites, etc. in the basin that may contribute point source contamination to surface and/or ground water.

Municipal lagoons, septic systems, and contaminated sites are potential sources of impacts to both surface and ground waters. Impacts may occur as a result of these activities because they are potential sources of nutrients, heavy metals, pathogens, and a variety of industrial and hydrocarbon chemical compounds.

This section provides a general description and assessment of municipal lagoons, septic systems and contaminated sites pertinent to the water quality of the Upper Assiniboine Basin based on information availability. Relevant government legislation and guidelines are also briefly discussed.

3.4.2 Municipal Lagoons

3.4.2.1 Description

Municipal wastewater lagoon treatment systems are composed of a primary cell and one or more secondary storage cells. The primary cell removes waste solids that readily settle out by gravity. In the secondary cells, wastewater undergoes secondary treatment that treats wastewater by employing biological organisms to consume and break down the organic material. Microorganisms, consisting of bacteria and other small organisms, consume wastewater solids containing dissolved carbohydrates, fats and proteins and other organic matter (SERM, 1993). The final stage is advanced or tertiary treatment that includes any process further upgrading wastewater quality.

A minimum of secondary treatment is required in Saskatchewan and Manitoba for municipal systems. Both provinces require a licence or permit to operate wastewater facilities. Most smaller communities rely on a lagoon system to achieve secondary treatment. Lagoons are shallow ponds lined in such a way that wastewater is prevented from leaching into the environment. The lining can be either composed of impervious clay, bentonite or an industrial product, depending upon site conditions (Fedeniuk, 1992). Two or more cells are required in Saskatchewan and Manitoba, with primary treatment occurring in the first cell(s) and secondary in the proceeding cells. The decomposition processes in the secondary treatment cells are usually a combination of anaerobic and aerobic processes. Some anaerobic activity may also occur in the first cell. Anaerobic decomposition usually occurs at the bottom layer of the lagoon because it relies on microorganisms that do not require oxygen to decompose organic matter and destroy pathogens. Residual solid materials from the primary treatment, referred to as sludge, are decomposed through anaerobic process and removed as required. Sludge may be disposed of by spreading it as a fertilizer on agricultural land or occasionally having it landfilled (SERM, 1993).

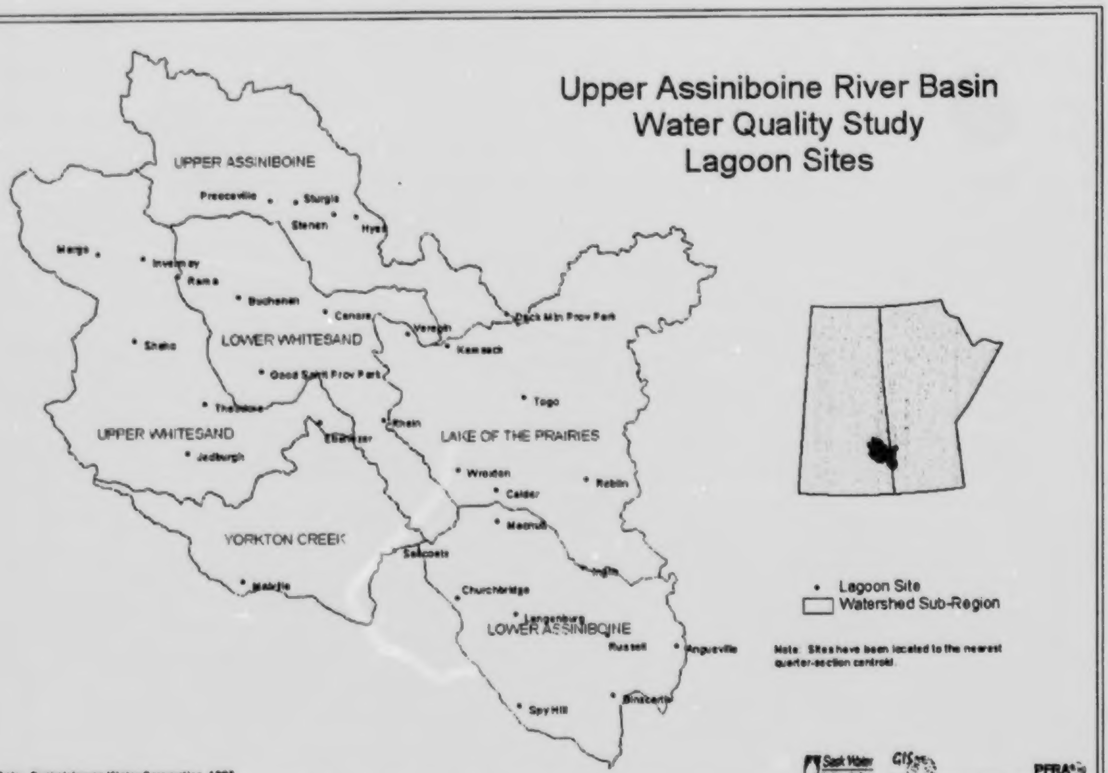
Aerobic processes, where microorganisms reliant on oxygen decompose organic matter, occur near the surface of a lagoon and are often facilitated by wind, sunlight, and algae growth. Wind mixes the lagoon water adding oxygen, while sunlight stimulates algae growth that in turn gives off oxygen. Occasionally, mechanical aeration is used to add oxygen to facilitate the aerobic process. Low temperatures impede the decomposition process by reducing the oxygen level in the lagoon. In the winter, only anaerobic processes are at work, considerably slowing the treatment of wastewater (SERM, 1993).

Figure 9 displays the licenced lagoon sites in the Basin. There are no observable patterns (i.e., areas of concentrated sites; areas of few sites) at this scale.

Both Saskatchewan and Manitoba have set minimum hydraulic storage requirements based on retention time between controlled discharges that normally occur once or twice a year (WCWWA, 1994). Lagoons are typically designed for 200 days storage with discharges to specified surface water bodies in the spring and fall. Some lagoons may continuously discharge. Lagoons have to be designed to retain wastewater for long periods due to winter conditions that inhibit biological treatment (Environment Canada, 1985). The lagoon at Kamsack, for example, discharges into the Assiniboine River in the spring and fall (Saskatchewan Environment and Public Safety, 1992). Others are only licenced to discharge in the spring. Yorkton has a mechanical wastewater treatment system that allows the City to discharge effluent into the receiving waterway continuously (SERM, 1993). The present lagoon system at Roblin uses irrigation as the only means of disposing of treated wastewater. There is a proposal to develop a wetland system to reduce the amount of effluent being irrigated and to polish the effluent and reduce the nitrate and phosphate levels in the effluent. Due to the size of the wetlands, it would only discharge into the eastern chain of lakes and into the Shell River during years of extremely wet weather (Conyette pers. comm., 1997).

Each province has design objectives which stipulate construction standards and pollution control mechanisms for lagoons. Many of these are aimed at protecting ground and surface water sources. Liner materials and depth, berms to avoid runoff, and consideration of aquifer location distance to surface water bodies, are some of the criteria outlined in the legislation. In Manitoba, this legislation includes Manitoba's Environment Act, the Water Works, Sewerage and Sewage Disposal Regulation of the Public Health Act, and Design Objectives for Standard Sewage Lagoons. Saskatchewan has similar restrictions which are covered under the Water Pollution Control and Water Works Regulations of the Environmental Management and Protection Act and The Water Corporation Act (WCWWA, 1994).

Figure 9 Recorded Lagoon Sites in the Basin


Upper Assiniboine River Basin
Water Quality Study
Lagoon Sites
UPPER ASSINIBOINE
Preeceville
Sturgis
Stenen
Hyas
Margo
Invermay
Rama
Buchanan
Canora
LOWER WHITESAND
Veregin
Duck Mtn Prov Park
Kamsack
Sheho
Good Spirit Prov Park
Togo
Theodore
Ebenezer
Rhein
UPPER WHITESAND
LAKE OF THE PRAIRIES
Jedburgh
Wroxton
Calder
Roblin
Macnutt
YORKTON CREEK
Saltcoats
Inglis
Melville
Churchbridge
Langenburg
LOWER ASSINIBOINE
Russell
Angusville
Binscarth
Spy Hill
• Lagoon Site
Watershed Sub-Region

Note: Sites have been located to the nearest quarter-section centroid.

Source: Site Data - Saskatchewan Water Corporation, 1997
Map Filename: /gis_dev/uarb/[illegible]/dillon/lagoon.eps

Effluent discharge quality and mixing zone size are outlined in the lagoon licence conditions established for each individual project and are designed to protect the receiving water body (SERM, 1997; Williamson, 1988a). The mixing zone is defined as the area adjacent to the point of discharge where receiving water quality may not meet surface water quality objectives. Waste and water are given an area to mix such that the water quality objectives are met at the boundaries of the mixing zone. The size of the mixing zone is determined on a case-by-case basis, but is designed to allow adequate passage of aquatic life.

Manitoba Environment (Williamson, 1988a) requires that the mixing zone meet the following requirements:

- Not lethal to aquatic life passing through the area.
- Not interfere with migratory routes essential to reproduction, growth, or survival of aquatic species.
- Not interfere with fish nurseries or spawning areas.
- Not cause irreversible organism response.
- Not contaminate sediments to increase chemical compound levels such that water quality objectives are exceeded (Williamson, 1988a).

Saskatchewan's requirements for mixing zones are similar. However, they also include specific requirements for the area directly adjacent to the effluent discharge, as well as the area of the mixing zone. Humans, wildlife, and aquatic species are not to be adversely affected by the quality of the effluent. Nutrient levels should be below concentrations that would result in eutrophication. In addition, the discharge should not use more than 30 percent of the assimilative capacity of the receiving water body when effluent is discharged by means of a diffuse outfall, or 10 percent when discharged from a point source outfall (SERM, 1997).

3.4.2.2 Assessment

Lagoons may have a variety of impacts on water quality for both the receiving water body and local aquifers. The following describe some of these impacts.

- High levels of bacteria may be present in discharge effluent that can contaminate the receiving water body and potentially impair drinking water, livestock watering, irrigation and/or recreation (Environment Canada, 1985).

- Heavy metals can be discharged which affect the desirability for drinking, irrigation, and livestock watering (CCME, 1987).

- Effluent can contain nutrients that enter water bodies. Partially treated sewage contributes phosphorus to waterways in a form that is bioavailable and thus readily taken up by aquatic vegetation and phytoplankton (Bircham and Bruneau, 1985).

- Aquatic organisms can be harmed by ammonia and hydrogen sulphide in the wastewater that are produced in part as byproducts of anaerobic microbe activity. Biological oxygen demand levels of this wastewater may also reduce available oxygen for aquatic biota (SERM, 1993).
- Lagoon seepage can damage adjacent land and contaminate ground water (SERM, 1993).
- Pesticides are also suspected of entering surface waters from municipal effluent (Gummer, 1979). However, there is little data on the levels of pesticides emanating from discharge effluent (Harker, 1997).

After disposing of treated effluent by discharging to streams, irrigating with wastewater and spreading sludge on agricultural land are the primary methods of dealing with treated waste matter (EPA, 1976). Many of the concerns are similar to spreading liquid and solid manure wastes.

Manitoba is also suspected of experiencing local ground water quality deterioration from the indirect infiltration of septic tanks as well as significant seepage from lagoons (Betcher et al., 1995). Saskatchewan is experiencing similar difficulties indicated by the findings of Maathuis (1991), Pupp, et. al. (1991), and Beckie (1990). However, there is relatively little published on these local contaminated incidents or on the impact such occurrences are having on the ground water quality in the Assiniboine River Basin.

A review of recent 1997 SERM data for the Yorkton area allowed a comparison of changes in water quality data relating to municipal discharges. Measurements taken from January 1974 to June 8, 1997 at Yorkton, Saskatchewan, one mile upstream, one mile downstream, and at the secondary effluent discharge indicate that some water quality changes result from municipal effluent discharge. Total phosphorus, for example, increased from a mean of 0.366 mg/L upstream to 2.635 mg/L one mile downstream of the effluent discharge. Nitrate plus nitrite also changed from a mean of 0.258 mg/L upstream to 2.026 mg/L downstream. This level remained below national and provincial drinking and livestock watering levels. One of the most dramatic changes was in fecal coliform levels. Upstream, the mean was 213.8/100 mL, while downstream of the effluent discharge the mean was 86 480.7 per 100 mL. This downstream level of fecal coliform exceeded provincial and national guidelines for drinking water, recreation, and irrigation (see Appendix 1).

3.4.3 Application of Municipal Effluent

3.4.3.1 Description

In relative terms, land application of municipal effluent has not been a common practice on the Canadian Prairies (Conyette, pers. comm., 1997). In the basin, the Town of Roblin is an example of a municipality in the basin that irrigates with a portion of its municipal effluent (Conyette, pers. comm., 1997). No published studies were located regarding the impact of these practices on water quality in the basin. Removal of sludge from municipal lagoons does not occur often (Environment Canada, 1985; EPA, 1976). When necessary, sludge may also be disposed of in municipal landfills or spread on agricultural lands. Because irrigation using municipal effluent is not widely practiced in the basin and sludge and disposal occurs infrequently, widespread reduction in water quality in the basin from such activities should not be expected.

3.4.3.2 Assessment

Land application of treated municipal sludge and liquid effluent has potential to affect both surface and ground water quality. This potential is linked to both the application of sludge and effluent and site characteristics. Application form (solid sludge or liquid effluent), chemical, nutrient and heavy metal concentrations, and amount spread, can affect water quality (Hogg and Tollefson, 1997). Metal contaminants, microorganisms, and nutrients can enter surface and ground water through runoff and erosion and leaching to subsurface water supplies (USCATST, 1992; Hogg and Tollefson, 1997).

Chang (1988) noted higher rates of nitrate leaching in liquid effluent in comparison to dewatered sludge, reflecting the additional water inputs. In addition, the study noted that nitrogen applications exceeding requirements always result in the accumulation of nitrate in the soil profile which can eventually leach to ground water. This has also been apparent in a recent study at Moose Jaw on treated municipal effluent disposal (Hogg and Tollefson, 1997).

Sludge and liquid effluent from municipal and agricultural waste contains trace metals. Land applications can redistribute these in the aquatic environment where they can be transferred through the food chain. Some are highly mobile and can leach to ground water or runoff (EPA, 1976). Others accumulate in surface soils where runoff can transfer trace metals to surface water bodies via eroded soils (USCATST, 1992; EPA, 1976).

Sludge is disposed of by land application or by landfilling. When sludge is applied to land, there is the potential for pathogen contamination of soil and subsurface water (Hogg and Tollefson, 1997). Two factors dictate the potential for a specific microbe to contaminate: survival rate and ability to migrate. The ability to survive outside a host is dependant upon the individual species and its susceptibility to a number of environmental conditions (EPA, 1976). Migration rates can also be affected by environmental factors and characteristics of the organism. For example, larger organisms generally migrate at a slower rate than smaller ones. Soil conditions such as organic content, pH, texture, and moisture can also influence migration rates. Denser soils such as clays are more likely to inhibit microbacteria movement. The ability to survive and migrate is also greatly dependent upon climatic conditions like moisture conditions and temperature. High moisture conditions can facilitate downward leaching while low temperatures can extend survival rates (Kowal, 1985; EPA, 1976). Spring melt waters and storm runoff may transfer pathogens to surface water bodies (USCATST, 1992). An analysis of shallow wells at Swift Current indicated fecal coliforms in tests wells following irrigation with municipal effluent. However, the method of detection used in this study was not precise and further study was recommended (Hogg and Tollefson, 1997).

The physical characteristics of each site can also affect changes in water quality. In general, the downward movement of water, called infiltration, is the most rapid through course textured soils such as sands. These will allow nitrogen, pathogens, and trace metals to penetrate the subsurface with the potential to infiltrate ground water quickly (USCATST, 1992).

As already noted, the limited practice of spreading sludge or irrigating with municipal waste in the basin means that this activity poses little threat to the basin at the present time.

3.4.4 Septic Systems

3.4.4.1 Description

The septic system is commonly composed of three parts: the septic tank, septic field, and surrounding soil. Household wastes are discharged into the tank, where solids settle out and grease and other surface material becomes surface scum. The discharge is broken down by anaerobic bacteria, which do not require oxygen to decompose the waste. Liquid effluent is then forwarded to the septic field where it is released to the surrounding soil area and decomposed by microorganisms (USCATST, 1992). In the septic tank, biological oxygen demand, coliforms, and suspended solids are dramatically decreased and dissolved oxygenic is increased. Decomposition continues in the septic field and surrounding soil (Bernhart, 1973). Septic system design is regulated under the Water Works, Sewerage and Sewage Disposal Regulation of the Public Health Act of Manitoba and the Plumbing and Drainage Regulation of the Public Health Act (1994) of Saskatchewan.

3.4.4.2 Assessment

Septic systems are a potential source of contamination of nearby surface water bodies and ground water quality. Even more than agricultural activities, they have been found to be a major source of ground water pollution in the United States (USCATST, 1992). Ali (1980) and Canter and Knox (1988) noted that septic systems are often found to be ineffective in disposing of sewage (as much as 50 percent of the systems surveyed). When contamination occurred, it was highest at the discharge point and decreased the greater the distance from the source. The rate of decrease varied with subsoil and hydrological factors, but in general the contaminant spread in a wedge shape in the direction of the ground water flow (Ali, 1980).

Septic systems have the potential to degrade ground water quality due to the nitrate formed in the treatment process. Nitrogen entering the septic tank is converted into ammonia by the anaerobic process, but after being released into the septic field and surrounding soil, aerobic bacteria convert it into nitrate where it may leach through the soil. It has been estimated that a septic system for a household of four can discharge the equivalent of 17 kg (38 pounds) of nitrogen per year (Canter and Knox, 1985). Septic systems have been found to contribute very little phosphorus to surface water bodies (Jones and Lee, 1977). While a limited number of septic systems in a given area typically have only minimal effects, an excessive number can impact ground water quality considerably. The number of septic tanks necessary to contaminate an area depends upon the physical nature of the area, including the soil structure, hydrogeology, and climatic conditions (USCATST, 1992). Exactly what might constitute an excessive number for the Assiniboine Basin would require further research.

Septic tanks have the potential to impact ground water quality negatively when they are improperly installed, or their performance has been inhibited in some manner. If seepage or discharge of untreated wastes occurs, they will contribute nitrogen, phosphorus, pathogens, and viruses to the subsurface that can then contaminate nearby wells used for domestic purposes (USCATST, 1992). Inadequate design, inappropriate installation, neglectful operation, or exhausted life expectancy, are ways septic systems may operate improperly (USEPA, 1993).

Inappropriate installation often involves improper siting, including locating in areas with inadequate separation distances from ground water, inadequate absorption area, sandy soils, inadequate soil permeability, or other conditions that do not allow adequate treatment of wastewater. Inappropriate installation can also include compaction of the soil bed by heavy equipment during construction, and improperly performed percolation tests. In terms of system operation, as many as 75 percent of all system failures have been attributed to hydraulic overload (USEPA, 1993). Also, regular inspection and maintenance necessary for proper functioning systems may not occur. Conventional septic systems are designed to operate over a specified period after which replacement is generally necessary. Homeowners may be unaware of the need for or unable to afford, a replacement (Hoover, 1996). Saskatchewan allows individual lagoons for any residence on a parcel of land greater than 40 acres in size as an alternative to a septic system (Campbell, pers. comm., 1998).

As already indicated, septic systems are a potentially a serious source of contamination of surface and ground water quality. Even more than agricultural activities, they have been found to be a major source of ground water pollution in the United States (USCATST, 1992). As much as 50 percent of septic systems may not be operating satisfactorily (Canter and Knox, 1988). Manitoba is also suspected of experiencing local ground water quality deterioration from the indirect infiltration of septic tanks as well as significant seepage from lagoons (Betcher et al., 1995). However, there is little published on these local contaminated incidents or on the impact such occurrences are having on the ground water quality in the Assiniboine Basin.

There are local instances of nitrate and coliform ground water contamination from septic systems and lagoons in the Assiniboine Basin. Maathuis (1991) indicated that septic systems may be a source of coliform contamination of the Collacott, Logan West and Bredenbury aquifers near Yorkton. There has been documentation of fecal coliform contamination of individual wells in the Yorkton area (Abrametz pers. comm., 1997). This is a widespread problem that is usually directly related to well construction, operation and maintenance, as well as adjacent land use activities (Canter and Knox, 1988). There is little published documentation on the frequency of septic or lagoon contamination although leaching is known to occur from municipal lagoons in both provinces (Betcher et al., 1995; Pupp, 1991). The Preeceville lagoon is one lagoon in the basin which is known to leach nitrates to underlying gravels (Beckie, 1990).

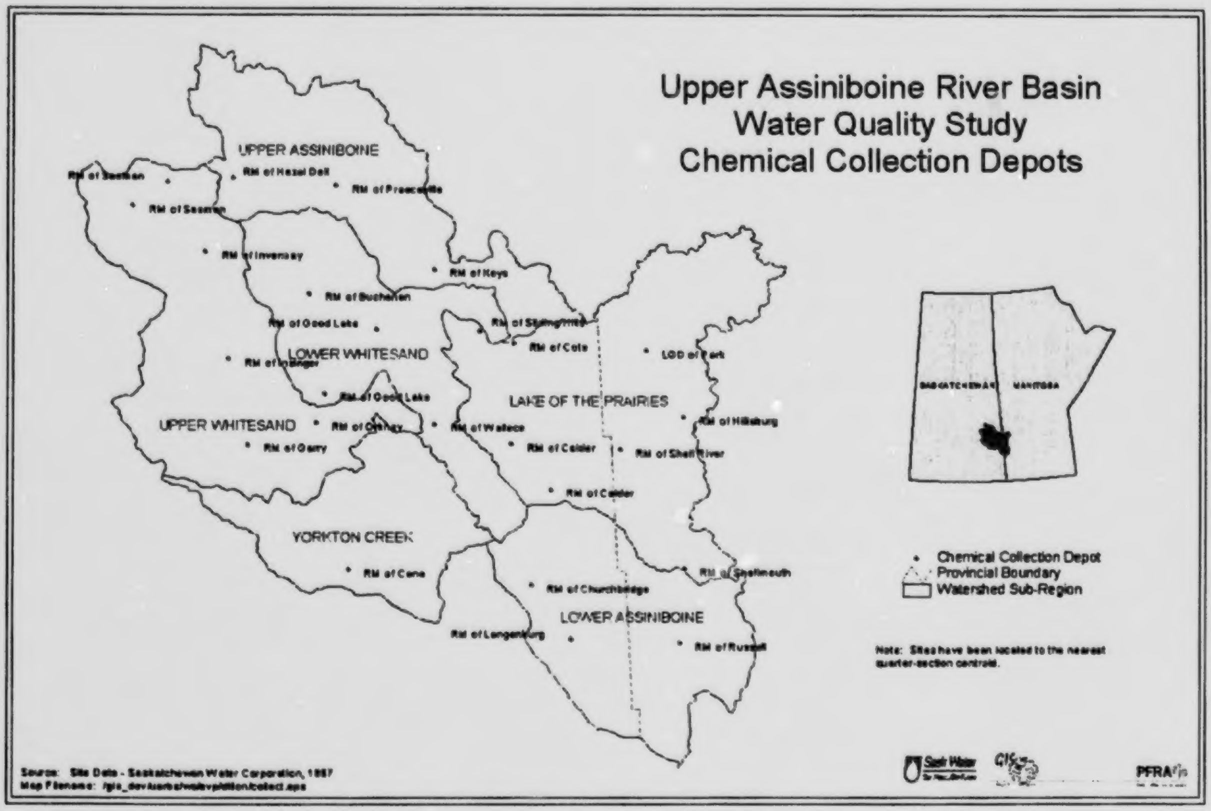
3.4.5 Contaminated Sites

3.4.5.1 Description

Contaminated sites are a form of point source pollution. Point source pollution, in contrast to nonpoint source pollution, emanates from one identifiable location. Point source pollution can arise from accidental spillages or the slow escape of chemicals over time from specific sites such as landfills, chemical storage sites, holding tanks, and industrial locations. The potential for contamination on local ground and surface waters is unique for each site and each contaminant.

As displayed in Figures 10 and 11, chemical collection depots and landfills are scattered throughout the Basin. In conjunction with industrial sites, these are a potential point source for contamination to the water. However, there is only one designated contaminated site in the basin, at Kamsack, Saskatchewan. This former industrial site has the potential to be leaching hydrocarbons and PCBs into ground water and through runoff, into the Assiniboine River (Macibroda Engineering, 1994).

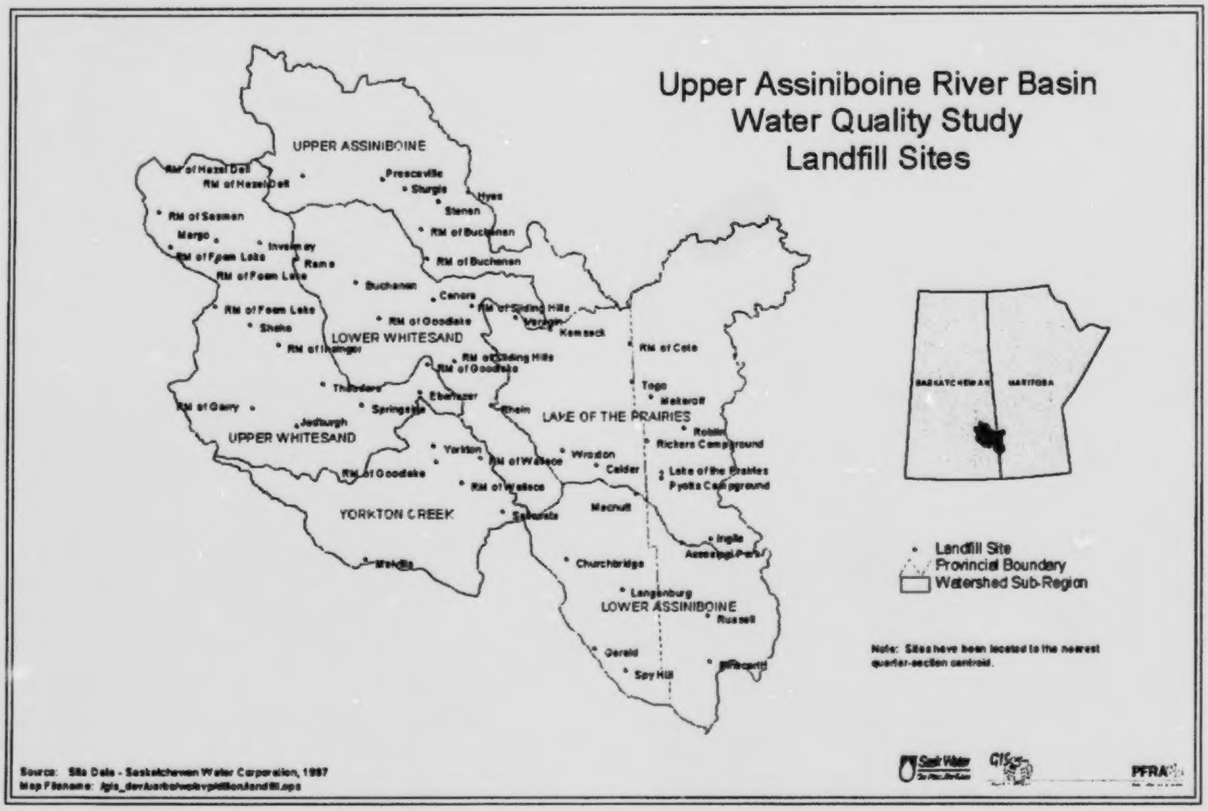
Figure 10 Chemical Collection Depots in the Basin


Upper Assiniboine River Basin
Water Quality Study
Chemical Collection Depots
UPPER ASSINIBOINE
RM of Sasman
RM of Hazel Dell
RM of Preeceville
RM of Sasman
RM of Invermay
RM of Keys
RM of Buchanan
RM of Good Lake
RM of Sliding Hills
RM of Cote
LOWER WHITESAND
RM of Insinger
LGD of Park
RM of Good Lake
LAKE OF THE PRAIRIES
UPPER WHITESAND
RM of Orkney
RM of Wallace
RM of Hillsburg
RM of Garry
RM of Calder
RM of Shell River
RM of Calder
YORKTON CREEK
RM of Cana
RM of Shellmouth
RM of Churchbridge
LOWER ASSINIBOINE
RM of Langenburg
RM of Russell
SASKATCHEWAN
MANITOBA
Chemical Collection Depot
Provincial Boundary
Watershed Sub-Region
Sask Water
GIS
PFRA

Note: Sites have been located to the nearest quarter-section centroid.

Source: Site Data - Saskatchewan Water Corporation, 1997
Map Filename: [illegible]

Figure 11 Landfill Sites in the Basin


Upper Assiniboine River Basin
Water Quality Study
Landfill Sites
UPPER ASSINIBOINE
LOWER WHITESAND
UPPER WHITESAND
YORKTON CREEK
LAKE OF THE PRAIRIES
LOWER ASSINIBOINE
RM of Hazel Dell
RM of Hazel Dell
Preeceville
Sturgis
Hyas
Stenen
RM of Sasman
Margo
Invermay
RM of Foam Lake
Rama
RM of Foam Lake
RM of Buchanan
RM of Buchanan
Buchanan
Canora
RM of Foam Lake
Sheho
RM of Goodeve
RM of Sliding Hills
Veregin
Kamsack
RM of Ituna
RM of Sliding Hills
RM of Goodeve
RM of Cote
Theodore
Ebenezer
Togo
Makaroff
RM of Garry
Jedburgh
Springside
Rhein
Roblin
Rickers Campground
Yorkton
RM of Wallace
Wroxton
Calder
Lake of the Prairies
Pyotts Campground
RM of Goodeve
RM of Wallace
Saltcoats
Machull
Melville
Churchbridge
Inglis
Asessippi Park
Langenburg
Russell
Gerald
Spy Hill
Binscarth
SASKATCHEWAN
MANITOBA
Landfill Site
Provincial Boundary
Watershed Sub-Region
SaskWater
GIS
PFRA

Note: Sites have been located to the nearest quarter-section centroid.

Source: Site Data - Saskatchewan Water Corporation, 1997
Map Filename: /gis_dev/uarbs/wqtsvp/dillon/landfill.aps

Since 1979, there have been approximately 200 hazardous material spills in the Saskatchewan portion of the basin. There are also over 80 landfills, many of which have been operating for decades and do not necessarily meet today's environmental standards for such operations (Betcher et al., 1995). For example, some have sloughs on site and others are situated in areas with high water tables and/or coarse soils. These conditions create opportunities for ground water contamination from the variety of hazardous wastes these sites may contain (SERM data). Maathuis (1991) has identified an old landfill at 36-25-04-W2 as a potential source of contamination of the Logan Aquifer. Other potential sources of concern are pesticide container storage sites scattered throughout the Assiniboine Basin. These sites are used to store used agricultural containers.

Manitoba has designated no hazardous sites within the Assiniboine Basin, but have identified numerous sites which have not been remediated to the Canadian Council of the Ministers of the Environment Agricultural criteria or to Manitoba's Level I criteria. These sites are located in Roblin, Russell, and Binscarth and are primarily service stations or petroleum storage sites and are likely leaching hydrocarbons into the surrounding subsurface (Betcher et al., 1995). Landfills are not listed as contaminated sites (Yee pers. comm., 1997); however, 94 landfills were identified in Manitoba as being a potential environmental risk.

3.4.5.2 Assessment

The ability for point source sites to contaminate local ground and surface waters is dependant upon the nature of the contaminant, design of the facility, and the site-specific environmental considerations (CCME, 1994). A knowledge of how various chemical and associated components persist and mobilize is critical in determining the risk that they pose to water quality. Site-specific characteristics are also factors in water contamination. Soil type can influence leaching potential and topography can influence the rate of runoff (EPA, 1976). Ground water close to the surface in an area with porous soils is at higher risk than sites with heavy clay and deep ground water (WCWWA, 1994).

Specific sites exist in both provinces for the disposal of agricultural chemical containers. Manitoba is currently operating six pesticide container disposal sites in the Assiniboine Basin under the Dangerous Goods Handling and Transportation Act. The regulations under the act require that surface and ground waters are protected with berms, the site is located a minimum distance of 100 m to surface water bodies, has a clay or synthetic liner, and evaporation ponds are present, if required. Licences must be obtained from Manitoba Environment for its operation (Manitoba Environment, Hazardous Waste Management Facility Operating Order). The Saskatchewan guidelines stipulate that the site must be located more than 500 m from a surface water body, and situated on soils with a high clay content. Runoff must be contained, and ground water recharge areas avoided. Approval is to be obtained from Saskatchewan Environment and Resource Management. Saskatchewan began operating these sites prior to implementation of the guidelines outlined above. Thus, container storage areas built before the guidelines may not adequately protect surface and ground water quality (Pupp et al., 1991).

No published studies were located on the impacts of chemical containers disposed of elsewhere such as landfills, prior to the development of storage sites. However, in an Alberta study of 75 pesticide container disposal sites, Burland and Byrtus (1992) found little evidence of ground water contamination. In addition, an analysis of canals and irrigation return devices found that herbicides broke down rapidly (within 24 hours), and insecticide levels were well below drinking water standards. Containers disposed at municipal landfills and other unsuitable sites prior to the development of disposal areas, likely pose a greater risk of contamination.

3.4.6 Summary

Larger communities typically require lagoons to treat effluent; smaller communities in remote areas often use septic systems, in an effort to reduce contaminant levels to acceptable levels. Landfills, industrial sites, and chemical storage facilities have the potential to be contaminated sites.

While guidelines have been developed for the design and operation of these facilities, the potential exists for surface and ground water to be contaminated with pathogens, nutrients, heavy metals, and pesticides. The susceptibility is related to aspects such as location, soil type, and timing of application/release.

There have been documented cases of water contamination from lagoons, septic systems, and contaminated sites in the basin.

4.0 GROUND WATER PROTECTION

4.1 General

The majority of rural users in Saskatchewan and Manitoba rely on ground water as a potable water source for domestic use and livestock watering (Hess, 1981). A number of urban centres in the basin, such as the towns of Yorkton, Langenberg, Churchbridge, Roblin and Russell, also rely on ground water as their sole source of potable municipal water supply. Others, such as Melville, and Preeceville, use a combination of ground and surface waters for municipal supply (Environment Canada, 1995).

Ground water quality in the basin has the potential to be impacted by a number of activities. Agricultural practices such as fertilizer application and manure spreading have the potential to introduce nutrients into the ground water. Nutrients can also be introduced through municipal lagoon seepage, septic systems, and effluent irrigation. In some instances, pathogens have been noted to enter ground water sources. Liquid waste materials can leach heavy metals to ground water. Industrial sites, such as landfills, also have the potential to introduce a variety of contaminants ranging from nutrients, hydrocarbons, heavy metals, pesticides, herbicides, and a variety of "exotic" chemicals, depending upon the use of the site.

Contamination of ground water supplies presents some unique difficulties. In general, contaminants in ground water degrade at slower rates than would occur in the aerobic conditions on the surface (Oleszkiewicz, 1995). Therefore, there is great potential for contaminants to accumulate over time. In addition, remediation of contaminated ground water is hampered by its subsurface location. Cleanup efforts are difficult and expensive. Contamination that has occurred through leaching may require not only the source of contamination be removed, but also the overlying soils through which the contaminant percolated.

This section provides a brief overview of the types of contamination risks to ground water, and then discusses the management of these concerns, including agencies involved, management approaches, monitoring and mapping, education and awareness, and long-term implications of current activities on ground water quality.

4.2 Types and Sources of Impacts

There are a variety of contaminants that have the potential to impair ground water quality in the Upper Assiniboine River Basin. This study focusses on the following:

- Nutrients
- Pesticides
- Heavy Metals
- Pathogens

Aquifers have varying susceptibilities to contamination depending upon the permeability of the overlaying till, the land use in the recharge area, and depth to aquifer. In Saskatchewan, studies of the aquifers in the Yorkton area (Maathuis, 1991) determined that the Collacott and Logan aquifers are highly susceptible to contamination from surface pollutants due to their near-surface locations. The Sturdee aquifer is also susceptible to contamination from accidental spills and agricultural runoff due to the permeability of the overlaying till and the depth ground water. Conversely, the Leech aquifer is considered to be well protected against contamination because of the thickness of the overlying till and the low intensity agriculture in the area. Another review of ground water quality was conducted for the Coté Indian Reserve (International Water Supply Limited, 1976). It was noted that of three abandoned Kamsack wells, two seals were broken and the wells were filled with debris. This may be an indication that abandoned wells in the region have not been properly sealed and maintained. Broken seals represent a direct pathway for surface runoff carrying nutrients, pesticides, and herbicides to enter ground water aquifers.

The following section provides an overview of the sources of each of these contaminants and characterizes the concerns in terms of potential impact.

4.3 Ground Water Management

4.3.1 Agencies Involved

There are a variety of agencies in both provinces involved with ground water management. In Manitoba, the Departments of Natural Resources, Water Resources Branch, and Manitoba Environment have primary responsibility for ground water resources. The Water Resources Branch is responsible for assessment and allocation of water resources and Manitoba Environment is responsible for issues related to ground water quality and regulation. Other agencies are involved in ground water management to a lesser degree. The Department of Rural Development, Water Services Board, and Manitoba Agriculture conduct ground water exploration and development of community and rural water projects including those related to ground water use. Manitoba Health has responsibility for ground water related to drinking water quality. The Clean Environment Commission has the authority to hold hearings into matters of environmental significance including ground water resources. Conservation Districts and municipalities also have authority to become involved with some aspects of ground water quality (Betcher et al., 1995).

Water quality in the Saskatchewan portion of the basin is the responsibility of four agencies. Sask Water's role parallels that of Manitoba Water Resources with more emphasis on management of ground water resources. Saskatchewan Environment and Resource Management (SERM) is responsible for water quality and Saskatchewan Health concentrates on drinking water issues. Saskatchewan Research Council (SRC) provides technical support to regulatory agencies, as well as research and investigations into management issues (Pupp et al., 1991).

The Federal government is involved with ground water issues and management through a couple of agencies. Prairie Farm Rehabilitation Administration (PFRA) funds ground water development projects in rural areas. Some ground water research has been carried out by the Geological Survey of Canada and the National Hydrology Research Institute. The Prairie Provinces Water Board (PPWB) has been involved in ground water issues at the provincial boundary (Betcher et al., 1995; Pupp et al., 1991).

These provincial and national agencies obtain their authority through a variety of legislation and regulations. A comprehensive description of provincial and national legislation and regulations related to ground water can be found in A Review of Ground Water Legislation in the Prairie Provinces (PPWB, 1991). At the present time, none of the above agencies have developed a specific management plan for ground water resources in the Upper Assiniboine Basin (Betcher pers. comm., 1997).

4.3.2 Management Approaches

4.3.2.1 General

There are generally two approaches to ground water management: voluntary (education, awareness, and incentives) and regulation and enforcement (Bertrand, 1995). Voluntary approaches are based on encouraging the individual to make the appropriate choices to reduce negative impacts on the resource. These choices can be influenced by a wide range of factors including education and research, economic incentives, and technical opportunities (USCATST, 1992; Bertrand, 1995). Codes of practice and guidelines developed by government agencies, businesses, and agricultural associations also fall under this category (Bertrand, 1995).

The regulations and enforcement approach requires the formalizing of requirements and prohibited activities by the stat such that they have the force of law. Enforcement involves the various activities undertaken to ensure that regulations are upheld.

Both approaches have been used with varying degrees of success for management of ground water resources in a number of jurisdictions. However, until ground water contamination is better understood in the basin, it is difficult to develop and justify a regulatory and enforcement system beyond the existing structure. Unfortunately, waiting until there has been sufficient ground water contamination to justify measures to protect the resource, essentially ignores the nature of ground water pollution: there is a lag time between the activities creating the problem and the problem itself. Regulations become a response mechanism rather than a forward looking policy that prevents contamination in the first place. In addition, regulations that respond to the current water quality often underestimate the real level of contamination facing aquifers (Flemming et al., 1995).

Some jurisdictions have begun with education and incentive programs geared to increasing awareness and the voluntary change of behaviour (Bertrand, 1995). Education is seen as a cost-effective means of increasing adoption of programs and policy practices. The advantage of an education, awareness, and incentives approach is that there is the possibility of voluntary public acceptance and awareness, and adoption of pollution prevention measures before regulation occurs (EPA, 1988). Problems with pollution control methods can be filtered out before approaches are legislated, and a high degree of public acceptance and support for the measures should technically already be in place. Those following environmentally friendly practices may even encourage legislation of the pollution control measures to ensure a level playing field in terms of economic competition and the maintenance of good water quality. Education is advocated as a policy strategy by the EPA as a means to develop a willingness to comply with regulatory conditions (USCATST, 1992). In Britain, a voluntary code of practice for agricultural activities was later adopted as law and a more regulatory and enforcement approach was taken (Bertrand, 1995).

In the Upper Assiniboine River Basin, the risk to ground water quality, as it is affected by land use practices, is not well understood. In this situation, an approach which begins with long-term commitment to education is a reasonable starting point. However, education must be accompanied with data collection, monitoring, and modelling of land use activities on the aquifers in the basin in order to understand and document baseline conditions and trends in water quality (Maathuis, 1991).

4.3.2.2 Agricultural Practices

Best Management Practices (BMPs) have been advocated as a direct means of communicating environmentally favourable choices to producers. BMPs are those practices developed specifically for a particular industry, such as agriculture, to protect the environment and the long-term sustainability of the industry. Implementation of BMPs for the basin, in terms of fertilizer, herbicide and pesticide use and application, may include the following considerations:

- Avoid nitrate leaching by managing nitrogen inputs to maximize efficient use by crops (USCATST, 1992; Green et. al.., 1994). This involves using chemical fertilizer and manure application rates based on crop need minus available nitrogen in the soil (Burton, 1996; SERM, 1997; Agriculture Guidelines Development Committee, 1994).

- Time the fertilizer or manure application relative to crop needs throughout its growth cycle and avoid application prior to wet weather that may lead to runoff and leaching.

- Protect water from chemical contamination by maintaining a suitable distance away from wells or sensitive areas during application, mixing, and loading of agricultural chemicals.

- Analyze soil for nutrient content to ensure fertilizer and manure application rates do not exceed nutrient needs.

- Eliminate fall applications of fertilizer which are more likely to result in leaching than spring applications (Blodgett, 1981). Leaving nitrates on land over the winter can cause them to percolate to the subsurface water supply during the spring melt, rather than contributing to crop development (Burton, 1986). This is even more critical in the case of porous sandy textured soils which tend to leach rather than hold nutrients (Zublena et al., 1995).

- Regularly test manure for nutrient levels and apply to fields based on crop need. The emphasis of manure spreading should be on manure utilization rather than waste disposal (Jacobs, 1994).
- Minimize field runoff by leaving a rough surface with mulch residue.
- Store chemicals in a safe place where they will not be subject to accidental spillage.
- Keep accurate records of pesticide, herbicide, and fertilizer inputs. Pesticide and fertilizer logs kept by individuals and companies can be used to mitigate use of pesticides under various environmental and land use conditions (Holden, 1986).
- Dispose of chemical containers properly at designated sites.
- Practice appropriate soil and water conservation practices.
- Avoid back siphoning into ground water when mixing agricultural chemicals.

4.3.2.3 Waste Disposal Siting and Design

While BMPs could theoretically be applied to waste disposal siting and design, legislation and guidelines are a more functional approach and have already been enacted to some extent by both provinces (Rentz, 1996). Protection of ground water requires that both municipal and manure storage systems are located on sites which are not prone to leaching to shallow aquifers, or that storage systems are properly engineered to limit leaching. Sewage works are legislated under a variety of acts in both provinces and contain clauses to protect ground water quality. In Saskatchewan, these include the Water Pollution Control and Waterworks Act, the Environmental Management and Protection Act, Saskatchewan Water Corporation Act, Water Quality Objectives and Guidelines for Application of Municipal Sewage Sludge to Land. Manitoba has similar array of legislation including the Waterworks, Sewage, and Sewage Disposal Regulation and the Design Objectives for Standard Sewage Lagoons.

Manitoba's Livestock Waste Regulation of the Environment Act and Saskatchewan's Agricultural Operations Act define the requirements for location and liners for earthen storages. Another condition of site suitability is the availability of a land base for spreading of potentially leachable material such as wastewater effluent, municipal sludge, and livestock manure. The Farm Management Guidelines developed for Manitoba (Manitoba Agriculture, 1995) address manure spreading, but as guidelines, compliance is voluntary. New Livestock Waste Regulations under the Manitoba Environment Act have recently been introduced and a number of the guideline provisions regarding manure management have been adopted. Saskatchewan has regulated manure management under provisions in the Agricultural Operations Act by requiring a manure waste management plan for certain classes of intensive livestock operations (Saskatchewan Agriculture and Food, 1997b).

There is some concern that the provinces are not being sufficiently proactive in planning for the location of large-scale livestock operations (Harker, 1997). Regional zoning and land use planning of acceptable locations for intensive livestock operations are possible means of ensuring vulnerable ground water resources are afforded a greater degree of protection.

4.3.2.4 Abandoned Well Management

A review of the published data indicated that while there are some concerns with ground water across the Prairies (including the basin), it is still of relatively good quality for drinking and livestock watering (Harker, 1997). This being the case, there is still time to plan and develop a comprehensive ground water strategy for the basin. In the interim, education and other voluntary programs could be initiated in areas of particular concern. One such area is abandoned wells.

Wells provide a direct route for surface contaminants to enter ground water sources and thus should be a priority for ground water protection efforts in the basin. There has been documentation of abandoned wells in the Kamsack area being improperly sealed (Banius, 1977). Both provinces have guidelines and legislation that require abandoned wells to be properly sealed. However, enforcement of that requirement is not occurring (Betcher pers. comm. 1997). Neither province has an abandoned well management/monitoring program, whereby wells are reviewed. This review would ensure they have been properly decommissioned by being capped with compacted clay after being filled with an appropriate material such as cement, bentonite or a clay mixture (Buchanan et al., 1996).

An abandoned well program was implemented in Kansas to address growing concern over nitrate, pesticide, and herbicide contamination of ground water. The approach began by clearly outlining the problem and developing a results oriented program focusing on prevention and protection. (Bossert, 1988). A review was undertaken to adjust the program part way through its mandate to ensure its goals were achieved.

The program identified abandoned wells using two approaches. A survey was distributed to land owners asking them to identify abandoned well locations on their properties. Remote sensing was used to confirm these locations and identify other well sites. A visual inspection was carried out to determine both the status and condition of each well. Appropriate policy and legislative structures were in place to ensure that remediation was carried out by land owners, if required, and state standards for recapping inactive and plugging abandoned wells were in place. An educational process was involved for contractors to ensure they were familiar with capping and plugging procedures and to ensure that the public was kept abreast of development and impacts on ground water (Bossert 1988). Such a program implemented in the basin would eliminate a direct pathway for herbicide, pesticide, nutrients, pathogens and other contaminants from entering ground water supplies.

4.3.3 Monitoring and Mapping

The ability to adequately manage ground water is dependent on a reasonable database of information. Hess (1981) has strongly recommended that ground water data be collected at regular intervals on municipal and rural supplies. In addition, Hess (1981) recommended the identification of critical areas requiring aquifer protection, in order to maintain the integrity of the water supply. To some extent, this process has begun in both provinces, although large information gaps exist and fiscal and staffing resources are insufficient for comprehensive base mapping and ongoing monitoring (Betcher et al., 1995).

Select monitoring of water levels and quality has been conducted by SRC for specific research purposes. From 1985 to 1987 Agriculture Canada monitored public water supplies and selected farm wells on the prairies for pesticide and herbicide residues. Site-specific monitoring is required in specific circumstances by SERM and Saskatchewan Health. This would include municipal and industrial sites such as landfills, municipal lagoons, and hazardous spill sites (Pupp et al., 1991). SERM is responsible for monitoring municipal and non-municipal wells with flow rates over 18 m^3 per day. Saskatchewan health monitors domestic and all other low flow wells. Little pesticide and herbicide residue monitoring occurs.

Aquifer mapping has been carried out for both bedrock and surficial aquifers for Saskatchewan, although mapping in the basin is not fully comprehensive (Maathuis, 1991). Efforts have been made to adopt a standard water quality coding system for all ground water quality data collected by Sask Water, Saskatchewan Research Council, SERM, and Saskatchewan Health (Pupp et al., 1991). Sask Water collects well drillers' reports, electric logs for boreholes, computerized records of licenced municipal and industrial water users, and various engineering reports. Saskatchewan Research Council also has some pre-1970s well data along with ongoing monitoring of investigation wells. Logs are kept on specific wells recording general water quality information such as major ions, iron, manganese, carbonate, bicarbonate, nitrates, sulfate, calcium, magnesium, chloride, phosphate, pH, total alkalinity, and total hardness. Pesticide, herbicide, pathogen, and hydrocarbon contamination data is not usually gathered. Sask Water is in the process of developing aquifer management plans for intensely used regions. The study of Yorkton ground water by Maathuis (1991) is the basis for a management plan for this area (Pupp et al., 1991).

Aquifer mapping has been carried out for Manitoba, but as with Saskatchewan, boundaries of aquifers and numerous small surficial aquifers are not well defined. In Manitoba, the Ground Water Pollution Hazard Mapping Study (Manitoba Natural Resources, 1978) delineated several areas in the basin that are potentially at risk for anthropogenic (human activities) contamination. These areas were determined based on distance from ground water to the surface and soil conditions. In Manitoba, water levels and a small amount of water quality monitoring is conducted by Water Resources Branch. Monitoring data is gathered intermittently, based on funding and staffing resources. In addition, it is primarily gathered to note major ion concentrations such as nitrate and not to monitor for contaminants such as pesticides, herbicides, or hydrocarbons (Betcher et al., 1995). To a much larger extent, water quality monitoring is carried out by Manitoba Environment, who conducts a comprehensive analysis on inorganic and some organic constituents from municipal ground water withdrawals. Monitoring is also carried out at selected landfill, lagoon, contaminated and hazardous spill sites (Betcher et al., 1995).

Mapping of aquifers across the Manitoba/Saskatchewan provincial boundary, carried out by the National Hydrology Research Institute, outlines the vulnerability of ground water sources to potential contamination. The criteria for this mapping were the thickness of the sedimentary layer above the uppermost saturated aquifer surface and the estimated hydraulic conductivity of each of the sedimentary layers. Land use activities which may have created point and non-point pollution sources were not considered (NHRI, 1995).

No published vulnerability mapping for Saskatchewan was found. However, Maathuis (1991) identified a number of aquifers in the Yorkton area which are susceptible to contamination as outlined below. The Collacott and Logan aquifers, due to their near-surface locations are highly susceptible to contamination from surface pollutants. The Leech aquifer is considered to be well protected against contamination because of the thickness of the overlying till and the low intensity agriculture in the area. The Sturdee aquifer faces potential contamination from accidental spills and agricultural runoff. Local instances of ground water contamination by nitrates and coliforms have been documented at the Logan West and Bredenbury aquifers near Yorkton (Maathuis 1991).

As mentioned previously, Manitoba Water Resources completed pollution hazard mapping in the 1970s. This mapping defined pollution hazard zones as areas where fresh water aquifers are overlain by less than 5 to 6 m of clays, tills, or other low-permeability materials (Betcher et al., 1995). A program to update these maps is underway, but has not been completed for the basin area (Betcher pers. comm., 1997).

Parts of the basin have been identified as areas vulnerable to pesticide ground water contamination based on soil conditions, topography, land use, climate, and depth to ground water (McRae, 1991). These areas are a site west of Yorkton, a region along the Assiniboine River near Kamsack - from west of Sturgis to the Coté Indian Reserve, the region surrounding the Good Spirit Lake, and along the Manitoba/ Saskatchewan boundary - from the northern tip of the Lake of the Prairies south to near Binscarth. The areas identified as vulnerable to pesticide contamination by McRae (1991) in Manitoba, do not correspond to those identified by Manitoba Water Resources. There is some correlation between the aquifers identified as at risk for contamination in the Yorkton region by Maathuis (1991) and this study by McRae (1991).

The existing data is insufficient, and is not structured to be easily accessible or adaptable to form a cohesive baseline for future monitoring of the Upper Assiniboine River Basin (ARMAB, 1996). Part of the reason is that the basin crosses jurisdictional boundaries with each province having a different approach to the management of watersheds. Voluntary and regulatory arrangements such as monitoring differ between the two provinces (PPWB, 1991; Betcher et al., 1995; Pupp et al., 1991).

Monitoring and analysis of river basins is an expensive and time consuming activity that, in the current climate of fiscal restraint, is difficult to undertake (Betcher et al., 1995). However, full scale monitoring of entire basins may not be desirable or even necessary (Natarajan and Rajagopal, 1994). Rather, to maximize monitoring resources, preference for comprehensive monitoring should be given to priority areas which are commonly defined as those at highest risk. This risk is based on hydrogeological conditions such as depth to aquifer, characteristics of the overlying till, and land use activities (Petty, 1988; Peter, 1988).

One important component of monitoring is analysis to identify water quality changes. This requires that sufficient and appropriate data be collected at regular intervals to allow trend analysis of variables, their relationship to other factors, and documentation of extremes. This information, specifically when compared with baseline information, can indicate potential impacts to ground water (Coffey, 1995). Comprehensive monitoring of ground water for pesticides should include not only water analysis, but measurements of pesticide leaching, application rates, times, methods, and climate conditions during and following application.

With baseline conditions identified, various modelling approaches and techniques can be applied to determine which is most accurate for this basin. There are many examples of integrating ground water models and Geographical Information Systems that store land use data, climatic, and topographical information (Reyes et al., 1995; Jabro et al., 1993; Srinivasan et al., 1994). Developing modelling mechanisms for the basin allows estimates of past, present, and future conditions. In the long-term, modelling can reduce the amount and/or frequency of data collected (Coffey, 1995). When used together, monitoring and modelling provides an opportunity to change regulatory systems, and implement appropriate volunteer approaches before significant negative water quality changes occur. Over the long-term, such measures can reduce or eliminate costly remediation, or the need to develop expensive alternatives to existing water supplies (Holden, 1986). They can also help identify activities which avoid or minimize risk to ground water (Roy, 1988). As an example, Maathius (1991) has recommended an inventory of sites potentially leaching contaminants and studies to confirm the boundaries of the Logan Aquifer System to the southeast of Yorkton. This will enable the development of appropriate management mechanisms to minimize or avoid future ground water quality problems.

4.3.4 Ground Water Protection Strategy

Ground water protection recognizes that prevention is the only satisfactory way of dealing with the potential for ground water contamination. In principle, the entire recharge area for a specific aquifer should be protected to avoid any change in the properties of ground water. However, protection of the entire recharge area is generally neither required nor realistic. There are two reasons why this is unnecessary to ensure the protection of water quality. First, the further the source of a contaminant, the greater its dilution by the time it reaches a withdrawal point such as a well. Second, for reactive and biological contaminants, the time available for attenuation is proportional to the distance travelled. Attenuation processes include adsorption on bedrock and soil materials, biochemical decomposition and, in the case of pathogens, slow biodegradation. Contaminants may enter the aquifer, but attenuation may be sufficient to prevent the substance from reaching the well. As a result, these processes may bring contaminant concentrations safely below the maximum acceptable levels for drinking water.

An aquifer protection strategy can be developed using ground water regeneration times as a basis for delineating the protection zones for the aquifer. Drawdown results from a ground water modelling exercise can be used to calculate ground water velocities for determination of various delay time zones. Once protection zones have been delineated, nonconforming or inconsistent land uses and practices are readily identifiable.

Protection strategies are often required to go beyond technical considerations. Most ground water protection strategies are based on risk assessments that take into account socioeconomic, technical, and legislative considerations. Since ground water is considered a multi-interest resource, there is generally some level of compromise between resource protection and land use priorities. A balance of resource utilization and technical considerations to make recommendations on an appropriate aquifer protection strategy is required.

4.3.5 Education/Awareness

Education is seen as a cost-effective means of increasing adoption of programs and practices. It is being advocated as a policy strategy by the EPA as a means to develop a willingness to comply with regulatory conditions (USCATST, 1992). A U.S. study has noted a need to educate agriculture operators comprehensively on how to minimize contamination of ground water (Holden 1986). Education is often at the forefront of how a policy or program is accepted by the receiving audience (USCATST, 1992). However, education is a complex process and getting the required information to the producer or municipal official can be difficult.

The literature has indicated that public education approaches for specific target audiences such as agricultural producers, should be designed to be comprehensive yet straightforward. Information packets should be clear, providing sufficient details without being overwhelming (Nowak, 1988). It has been suggested that one reason why BMPs have not been more readily adopted is because the producer has not been presented with comprehensive information regarding the profitability and environmental benefits of adopting the recommended practices (Feather and Amacher, 1994). Furthermore, it has been suggested that the education strategy must be related to existing farm management practices. A review of specific practices used in the target area are necessary to determine which ones can realistically be changed. Research should be done to determine how and when practices such as soil testing and fertilizing are conducted and what influences the producers' choice of crops on a year-to-year basis (Nowak, 1988). A good example in this basin is the tillage method used by some farmers in the Yorkton region. Due to the large quantities of straw residue produced, many farmers find reduced tillage (where the straw is partially incorporated) to be more practical than no-till systems (where residue sits on the surface) (Abrametz pers. comm., 1997).

Studies in the United States and Canada have determined that agricultural education programs do not necessarily reach their target audience: the producer, municipal official, or contractor, depending upon the circumstance (Corey, 1988; USCATST, 1992; Harker, 1997). The format as well as the content must be geared to the target audience or the information on the benefits and methods of water quality protection become difficult to communicate (Corey, 1988). The Fact Sheets produced by Green and Roberts (1994a, 1994b) on behalf of Saskatchewan Agriculture and PFRA are examples of an information pamphlet produced for an identified audience on a specific topic. Concerns have also been levelled that information on agricultural practices, particularly as they relate to impacts on ground water quality, can be contradictory or confusing (Harker, 1997). In such circumstances, the producer is unclear as to the best way to proceed.

4.3.6 Long-Term Water Quality Implications

There is the potential that long-term ground water quality in the basin as with the rest of the Canadian Prairies will degrade from its current level as a result of human activities (Harker, 1997). However, with the minimal amount of data and studies on land use activities and ground water supplies in the basin, it is very difficult to project with any certainty the future changes in water quality that may occur due to anthropogenetic activities. What has become apparent from the review of the literature is that there is an urgent need for systematic data gathering and/or analysis of the ground water resources, particularly with the high level of dependence in the basin on ground water as a primary source of municipal and rural drinking, and livestock watering supply.

Studies in southern Saskatchewan and Manitoba highlight the degree of nitrate contamination that has been found in the subsurface waters below agricultural land. A long-term study would help to identify trends resulting under various agricultural activities and practices, as well as provide information on rate of nitrate accumulation in the lower subsurface and its contamination of ground water supplies.

The projected increase in the use of herbicides for conservation and reduced tillage systems highlights a potential for increased penetration of agriculture chemicals into ground water supplies (Monenco Consultants Limited, 1991). The current rate of use is unclear for the basin as is the current status of ground water with respect to herbicide residues.

Abandoned wells have become an issue following the 1997 flood of the Red River Valley as the primary source for pathogens and other contaminants to enter ground water supplies (Bauer, 1997). Since wells represent a direct pathway to ground water supplies, the longer these contamination routes are allowed to remain viable, the greater the opportunity for contamination of local aquifer sources. While both provinces have guidelines that require landowners to properly seal abandoned wells, the lack of enforcement has meant that in Manitoba alone it is estimated that there are 10,000 improperly sealed wells (Betcher pers. comm., 1997). This would seem to indicate that there is an need to address the issue of abandoned wells as an immediate step to reducing the potential for contamination of ground water resources. Other programs to seal abandoned well elsewhere (Bossert, 1988) have been very successful at demonstrating a rapid reduction in contaminant loading of aquifers from these sources.

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APPENDIX 1

CCME WATER QUALITY GUIDELINES
MANITOBA AND SASKATCHEWAN SURFACE WATER OBJECTIVES

GUIDELINES AND OBJECTIVES FOR 'NUTRIENTS AND DISSOLVED OXYGEN'

Parameters	CCME*			Saskatchewan**		Manitoba***		
	Drinking Water mg/L	Freshwater Aquatic Life mg/L	Livestock Watering mg/L	Freshwater Aquatic Life mg/L	Livestock Watering mg/L	Domestic Consumption mg/L	Freshwater Aquatic Life mg/L	Livestock Watering mg/L
Ammonia (total)		1.37-2.2 [2]						
Nitrate	45 [12]	avoid excessive weed growth				10.0		
Nitrite	3.2 [12]	0.06	10.0			1.0		
Nitrate + Nitrite			100.0		100.0			10.0
Total Phosphorous				avoid excessive weed growth			avoid excessive weed growth	
Total Dissolved Oxygen		5.0-9.5		≤5.0	≤5.0		47% saturation	maintain aerobic conditions

[2] guideline changes with pH and temperature
[12] equivalent to 10.0 mg/L nitrate and nitrogen and 1.0 mg/L of nitrite as nitrogen

GUIDELINES AND OBJECTIVES FOR MICROBIAL PARAMETERS

Parameters	CCME*			Saskatchewan**		Manitoba***	
	Drinking Water	Recreation	Irrigation	Recreation	Livestock Watering	Domestic Consumption	Recreation
Microcystin L-R	1.5 µg/L				avoid waters with blue-green algae		
Coliforms, fecal	0/100 mL	200/100 mL [b,c]	100/100 mL	200/100 mL [b,c]			200/100 mL [b,c]
Coliforms, total	10/100 mL	5000/100 mL [d]	1000/100 mL	5000/100 mL [d]			5000/100 mL [d]

[b] contact 200/100 mL of 5 tests minimum over a 30-day period
[c] non-contact 1000/100 mL of 5 tests minimum over a 30-day period
[d] non-contact 5000/100 mL tests minimum over a 30-day period

* adapted from CCME Inorganic Parameters
** adapted from Saskatchewan's Surface Water Quality Objectives (SERM 1997)
*** adapted from Manitoba's Surface Water Quality Objectives (Manitoba Environment 1988)

GUIDELINES AND OBJECTIVES FOR TRACE METALS

Parameters	CCME*				Saskatchewan**		Manitoba***			
	Drinking Water mg/L	Freshwater Aquatic Life mg/L	Irrigation mg/L	Livestock Watering mg/L	Freshwater Aquatic Life mg/L	Livestock Watering mg/L	Domestic Consumption mg/L	Freshwater Aquatic Life mg/L	Irrigation mg/L	Livestock Watering mg/L
Aluminum (total)	[10]	0.005-0.1 [5]	5.0	5.0		5.0			20	5.0
Arsenic (total)	0.025	0.05 [10]	0.1 [10]	0.5-5.0 [10]	0.05	0.5	0.025	0.19	2.0	0.5
Barium	1.0				1.0		1.0			
Beryllium	[10]		0.1	0.1		0.1			0.5	
Boron (total)	5.0 [8]		0.5-6.0	5.0		5.0	5.0		2.0	5.0
Cadmium (total)	0.005	0.0002-0.0018 [1, 10]	0.01	0.02	0.001	0.02	0.005	0.00066-0.002		0.02
Chromium (total)	0.05	0.002-0.02	0.1	1.0	0.02	1.0	0.05	0.011	[1]	1.0
Cobalt (total)	[10]		0.05	1.0		1.0			[5]	1.0
Copper (total)	≤1.0	0.002-0.004 [1]	0.2-1.0 [4]	0.5-5.0	0.01	0.5-5.0 [a]	≤1.0	0.0065-0.021	[5]	1.0
Lead (total)	0.01	0.001-0.007 [1]	0.2	0.1	0.02	0.1	0.01	0.0013-0.0077	10.0	0.5
Mercury (total)	0.001	0.0001		0.003	0.0001	0.003	0.001	<0.0001		0.003
Nickel (total)	[10]	0.025-0.15 [1]	0.2	1.0	0.025-0.10	1.0		0.056-0.16	2.0	5.0
Selenium (total)	0.01	0.001	0.02-0.05	0.05	0.01	0.05	0.01	0.035	0.05	0.05
Silver (total)		0.0001			0.01			0.0001		
Zinc (total)	≤5.0	0.03	1.0-5.0	50	0.05		≤5.0	0.047	10	50

* adapted from CCME Inorganic Parameters
** adapted from Saskatchewan's Surface Water Quality Objectives (SERM 1997)
*** adapted from Manitoba's Surface Water Quality Objectives (Manitoba Environment 1988)
[a] 1.0 mg/L cattle, 5.0 mg/L hog & poultry, 0.5 mg/L sheep
[1] guideline changes with hardness
[2] guideline changes with pH and temperature
[4] guideline varies with crop type
[5] guideline changes with pH, calcium, and dissolved carbon
[8] interim guideline
[10] under review
[12] equivalent to 10.0 mg/L nitrate and nitrogen and 1.0 mg/L of nitrite as nitrogen

APPENDIX 2

PRAIRIE PROVINCES WATER BOARD WATER QUALITY OBJECTIVES ASSINIBOINE RIVER

Water Quality Objectives
Assiniboine River Reach: Whitesand River to outlet of Shellmouth Reservoir

Chemical, Physical, or Biological Variable	Acceptable Limit(s)
Arsenic (diss)	0.05
Barium (total)	1.0
Boron (diss)	2.0
Cadmium (total)	0.001
Chloride (diss)	100.0
Chromium (total)	0.011
Copper (total)	0.01
Fecal Coliform	200/100 mL
Fluoride (diss)	1.0
Iron (diss)	0.3
Lead (total)	0.02
Manganese (diss)	0.05
Nickel (total)	0.10
$NO_2 + NO_3$ (as N)	10.0
Selenium (diss)	0.01
Sodium (diss)	100
Sulphate (diss)	500
Uranium	0.02
Zinc (total)	0.047
Phosphorous (total)	0.05
Ammonia (total)	see next table
Oxygen (diss)	6.0
pH (pH units)	6.5-9.0
Lindane	0.00008
2,4-D	0.004
2,4,5-TP	0.01
Chlorophenols (total)	0.001
Chlorine	0.002
Cyanide (free)	0.005
PCP	0.0005
Cesium-137 (Bq/L)	50
Iodine-131 (Bq/L)	10
Radium-226 (Bq/L)	1.0
Strontium-90 (Bq/L)	10
Tritium (Bq/L)	40000
Mercury in Fish (µg/L)	0.5
PCB in Fish (µg/L)	2.0

all units are in mg/L, unless otherwise noted

Total Ammonia Nitrogen

Excerpt from the *Surface Water Quality Objectives*
Water Quality Branch, Saskatchewan Environment and Public Safety
November 1988 (WQ 110)

Total Ammonia Nitrogen (mg/L)

Note: The toxicity of ammonia relates primarily to the unionized form (NH_3). The concentration of unionized ammonia present in water increases with pH and temperature. The values below represent total ammonia-nitrogen concentrations (at various temperatures and pH levels above which accompanying NH_3 concentrations may be harmful to aquatic life.

Total Ammonia (NH_3 + NH_4+)
maximum levels expressed as N at various pH/temperature conditions

pH	Water Temperature (°C)						
	0	5	10	15	20	25	30
6.50	2.06	1.97	1.81	1.81	1.22	0.85	0.60
6.75	2.06	1.97	1.81	1.81	1.22	0.85	0.61
7.00	2.06	1.97	1.81	1.81	1.22	0.85	0.61
7.25	2.06	1.97	1.81	1.81	1.23	0.86	0.61
7.50	2.06	1.97	1.81	1.81	1.23	0.87	0.62
7.75	1.89	1.81	1.73	1.64	1.15	0.81	0.58
8.00	1.26	1.18	1.13	1.09	0.76	0.54	0.39
8.25	0.72	0.67	0.64	0.62	0.44	0.32	0.23
8.50	0.40	0.39	0.37	0.37	0.26	0.19	0.15
8.75	0.23	0.22	0.21	0.22	0.16	0.12	0.09
9.00	0.13	0.13	0.13	0.13	0.11	0.08	0.06

APPENDIX 3

COMMON HERBICIDES USED IN THE UPPER ASSINIBOINE RIVER

Guidelines and Objectives for Pesticides and Herbicides Common to the Assiniboine River Basin

	CCME								Sask**	Manitoba	
Parameters	**Drinking Water mg/L**	***Interim Guideline***	**Freshwater Aquatic Life mg/L**	***Interim Guideline***	**Irrigation mg/L**	***Interim Guideline***	**Livestock Watering mg/L**	***Interim Guideline***	**Freshwater Aquatic Life mg/L**	**Domestic Consumption mg/L**	**Wildlife & Aquatic Life mg/L**
Aldrin	0.001		0.00006								
Atrazine+N-dealkylated metabolites	0.005	*8*	0.002		0.01 interim		0.06	*8*			
Azinphos-methyl	0.02										
Bromoxynil	0.005	*8*	0.005		0.00035		0.011	*8*			
Carbaryl	0.09									0.07	
Carbofuran	0.09		0.00175				0.045				
Chlorpyrifos	0.09										
Cyanazine	0.01	*8*	0.002	*8*	0.0005	*8*	0.01	*8*			
2,4-D	0.1	*8*	0.004				0.1	*8*	0.004	0.1	
DDT	0.03	*10*	0.000001							0.03	0.000001
Dicamba	0.12		0.01	*8*	0.000006		0.122				
Diclofop-methyl	0.09		0.0061		0.00018		0.009	*8*			
Dimethoate	0.02	*8*	0.0062	*8*			0.003	*8*			
Endosulfan			0.00002								0.000056
Glyphosate	0.28	*8*	0.065	*8*			0.28	*8*			0.065
Lindane	0.004								0.001	0.004	0.0001
Malathion	0.19										
Methyl-4-chlorophenoxya cetic acid, 2- (MCPA)			0.0026	*8*	0.0026		0.025				0.0026
Metolachlor	0.05	*8*	0.008		0.028	*8*	0.05	*8*		0.05	0.008
Phorate	0.002	*8*								0.002	
Triallate	0.23		0.00024	*8*			0.23	*8*		0.23	
Trifluralin	0.045	*8*	0.0001				0.045	*8*		0.045	

*Adapted from CCME Inorganic Parameters

**Adapted from Saskatchewan's Surface Water Quality Objectives (SERM 1997)

**Adapted from Manitoba's Surface Water Quality Objectives (Manitoba Environment 1988)

Appendix III

Water Quality Trends in the Assiniboine River at the Interprovincial Boundary

Prepared for:
The Upper Assiniboine River Basin Water Quality Study
Water Quality Technical Committee

G.W. Dunn, Environment Canada
Environmental Conservation Branch
January 1999, 80 p.

WATER QUALITY TRENDS

IN THE

ASSINIBOINE RIVER

AT THE INTERPROVINCIAL BOUNDARY

Prepared for the
Upper Assiniboine Basin Study
Water Quality Technical Committee
by:

G.W. Dunn
Environment Canada
Environmental Conservation Branch
January 1999

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ABSTRACT

Assiniboine River water quality data for the period 1981 to 1997 was examined for long-term trends. If water quality data was not available for this period then long-term trends were determined for 1974 to 1993. Monthly data for the period of record was also run through a series of non-parametric trend analysis tests recommended by Dr. El-Shaarawi in his 1991 report entitled "Trend Assessment Techniques: Application to Prairie Provinces Water Board Water Quality Data Set".

The river data was carefully reviewed and verified prior to conducting the trend analysis tests. To ensure that false long-term trends were not predicted, spill events were removed from the data base. Method changes for each variable were reviewed to ensure that trends identified by statistical trend analysis were not a result of a change in analytical method or a change in detection limit.

Time series graphs for each variable with the least squares best fit lines, significance of slope statistics and the Lowess smooth curves were prepared. These graphs were used to identify seasonality in the data base, detection limit changes, and to verify long-term non-parametric trend results.

Non-parametric trend tests were conducted on the individual months to identify a pattern in water quality changes and similar tests were run on the entire data base to determine long-term trends in water quality. The results of trend analyses indicated that long-term changes occur in concentrations of certain variables collected from the Assiniboine River near the interprovincial boundary. A summary of test results is shown in Table 1.

The tests determined that there was no variable that showed a significant long-term increasing trend. Levels of 2,4,5-T and 2,4-D appeared to be increasing, according to non-parametric trend test results, but it was further determined that these trends were only a result of a change in the analytical detection limit.

Long-term negative trends were determined in total nickel, fecal coliforms and in alpha BHC. Long-term negative trends were also identified for boron, iron, copper, nickel, mercury and lead levels but further investigation determined that these trends were directly related to a change in analytical method or detection limit and were not a result of a change in water quality conditions at the site.

A review of the detailed data, a study of excursions to the PPWB Water Quality Objectives and the determination of trends were used to determine variables that may affect downstream users in the basin. Dissolved oxygen, total phosphorus and manganese are constituents, now being monitored in the Assiniboine River at the interprovincial boundary, which are now at levels of potential concern to downstream users. Although none of these three variables have been increasing in the river, they do occasionally exceed the PPWB Objective.

The report recommendations are that:

- concentrations of dissolved oxygen, total phosphorus and dissolved manganese be watched closely and that monitoring for these variables be continued in the river at an appropriate frequency for determining long-term trends;
- methods of improving the effluent quality from the town of Kamsack be studied. This was also recommended by the 1991 Saskatchewan Environment study. A reduction of total phosphorus in the sewage effluent would reduce the potential for accelerated aquatic weed and algae growth in the Assiniboine River.

TABLE 1. Summary Results Of Trend Statistics

For the Assiniboine River

Water Quality Variables	# of Months with Trend	Significant Trend Over Period Of Record	Rate of Change mg/L/yr	Management Implications
TDS	1	None	0.0000	NC/ no trend, no obj.
CONDUCTIVITY	1	None	-0.6667 μg/cm/yr	NC/ + trend, no obj., low levels
TURBIDITY	0	None	0.1857 JTU's/yr	NC/ no trend, no obj.
BORON (DISS.)	10	~~Negative~~	-0.0091	NC no trend, well below obj.
NO2+NO3	1	None	0.0020	NC/ no trend, well below obj.
AMMONIA (TOTAL)	1	None	-0.0020	NC/ no trend, rarely exceed obj.
TOTAL NITROGEN	1	None	0.0155	NC/ no trend, no obj.
PH (FIELD)	0	None	-0.0011 pH units/yr	NC/ no + trend, below obj.
DISSOLVED OXYGEN	1	None	-0.0500	PC/no trend, levels above obj.
NFR	1	None	0.1333	NC/ no trend, no obj.
SODIUM (DISS.)	1	None	-0.1472	NC/ no trend, below obj.
PHOSPHORUS(TOTAL)	0	None	0.0006	PC/ no trend, levels above obj.
SULPHATE (DISS.)	0	None	0.4167	NC/ no trend, well below obj.
CHLORIDE (DISS.)	0	None	-0.0171	NC/ no trend, well below obj.
a - BHC	9	Negative	-0.0003 μg/L/yr	NC/-trend for 1974-93, no obj.
CALCIUM (DISS.)	1	None	-0.0786	NC/ no trend, no obj.
MANGANESE (DISS.)	0	None	-0.0001	PC/ no trend,1974-93exceed obj.
IRON (DISS.)	2	~~Negative~~	-0.0009	NC/no trend 1974-93 below obj.
COPPER (TOTAL)	2	~~Negative~~	0.0000	NC/ no trend, below obj.
ZINC (TOTAL)	0	None	0.0000	NC/ no trend, below obj.
NICKEL (TOTAL)	6	Negative	1.0 No./100 ml/yr	NC/ no trend, well below obj.
FECAL COLIFORMS	0	Negative	-0.6 No./100 ml/yr	NC/- trend 1974-93, below obj.
MERCURY (TOTAL)	10	~~Negative~~	0.0000 μg/L/yr	NC/ no trend 1974-93, no obj.
LEAD (TOTAL)	10	~~Negative~~ *	-0.0003	NC/no trend, below obj.
2,4,5 - T	12	~~Positive~~	0.0000 μg/L/yr	NC/ notrend 1974-93 below obj.
2,4 - D	2	~~Positive~~	0.0007 μg/L/yr	NC/ notrend 1974-93 below obj.
Var. with Positive Trend		0		
Var. with Negative Trend		3		

~~Negative~~ or ~~Positive~~ - Result influenced by method change
* - Significant Inhomogeneity at .05 Level
☐ - Indicates Variable could be a Potential Concern to Users
NC - Variable is not a concern
PC - Variable is a potential concern

INTRODUCTION

Background of Water Quality Trend Analysis

Only one monitoring site in the Upper Assiniboine River basin had sufficient monitoring data to conduct long-term trend analysis. That site is the PPWB (Prairie Provinces Water Board) monitoring site on the Assiniboine River near Kamsack (00SA05MD0002). Since the signing of the 1969 Master Agreement on Apportionment the Prairie Provinces Water Board (PPWB) has been involved in interjurisdictional water quality management. The PPWB's mandate is "to foster and facilitate interprovincial water quality management among the parties that encourages the protection and restoration of the aquatic environment."

The Assiniboine River PPWB site is one of eleven water quality monitoring stations located near the Alberta-Saskatchewan and Saskatchewan-Manitoba boundaries to carry out the responsibilities as defined in the 1969 Master Agreement on Apportionment. Since April 1974 regular monthly water quality monitoring has been conducted at this station by the Water Quality Branch of Environment Canada. The monitoring program results are used to compare with the PPWB Water Quality Objectives and determine long-term trends in water quality at the interprovincial boundaries.

The Board approved the use of it's reach specific PPWB Water Quality Objectives in 1990 to replace the general 1973 Interim Water Quality Objectives. In many cases, the objectives were established at levels, much higher than background concentrations in interprovincial streams. Consequently, the Board felt that there was a need for trend assessments to ensure the Board was made aware of increasing levels or deteriorating trends in water quality long before a PPWB Water Quality Objective was exceeded and a downstream use was threatened.

The PPWB Water Quality Program is a preventative and proactive approach to interprovincial water quality management and promotes the protection and restoration of the aquatic environment. In order to inform the agencies on whether the water quality is improving or getting worse on interprovincial streams the PPWB conducts trend analysis on a periodic bases. The PPWB, as well, keeps informed on regional and environmental trends in order to deal with water quality issues and to meet the goals and objectives of the water monitoring program.

The detection of small changes over time, which can be an indication of potential deterioration of the water resource, are difficult if not impossible to determine without trend analysis techniques. Trend analysis is, therefore, an integral component of the PPWB Water Quality Program. Trend analysis is required because variables that exceed the objectives may not identify all issues on interprovincial streams. The analysis ensures that significant changes in water quality are detected, evaluated and, if deemed necessary, remedial action is taken to resolve any concerns before an objective is exceeded.

Purpose of Report

This report was prepared to assist the Upper Assiniboine Basin, Technical Committee on Water Quality in identifying potential interprovincial water quality concerns on the Assiniboine River and help the study management group assess trends in water quality and water quality management policies. Information from the report can also be used to assist provincial agencies in a review of their water quality monitoring programs on the prairies.

STUDY AREA

Assiniboine River Basin Characteristics

Physical Features

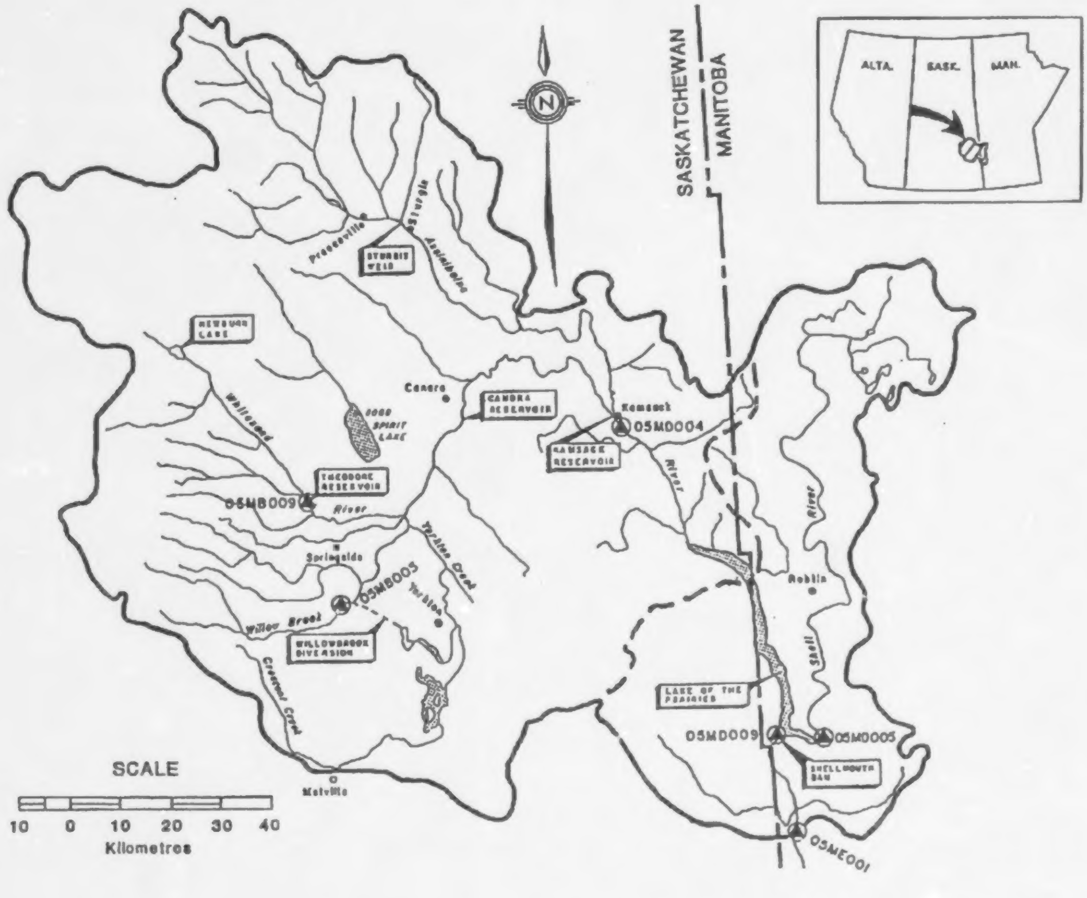
Almost all of the Assiniboine River basin in Saskatchewan is tributary to the hydrometric gauging station on the Assiniboine River near Kamsack (00SA05MD002). The gross drainage area measured by the hydrometric station is 12 954 km^2 and the effective drainage area is 4 324 km^2 (see Figure 1).

The main tributary of the Assiniboine River is the Whitesand River that joins the Assiniboine just above Kamsack. The Whitesand River has several tributaries including Yorkton Creek and Willowbrook Creek. There is also a major recreational lake in the non-contributing area of the Assiniboine River basin, Good Spirit Lake.

The basin is primarily agricultural and, while there have been some reservoirs built in the basin, for the most part the waters have not been intensively used or developed. The communities of Yorkton, Canora and Kamsack are in the central part of the basin, and immediately downstream from the interprovincial hydrometric station. Below the station is the Lake of the Prairies, a major reservoir in Manitoba that backs up water across the Manitoba-Saskatchewan interprovincial boundary into Saskatchewan.

The Assiniboine River at the Saskatchewan-Manitoba interprovincial boundary drains a relatively homogeneous area of Saskatchewan. When the glaciers retreated some 9 000 years ago, the Assiniboine River was cut into the topography by erosion to its present size. Clay, silt, sand and gravel, typical glacial debris derived from the erosion of the upstream areas and from newly deposited glacial sediment, continued to be carried downstream with the sand and gravel outwash from glacial areas.

Figure 1. Key Map of the Assiniboine River Basin


N
SASKATCHEWAN
MANITOBA
ALTA.
SASK.
MAN.
Preeceville
Sturgis
STURGIS WEIR
Assiniboine
NEWBURN LAKE
Whitesand
Canora
CANORA RESERVOIR
GOOD SPIRIT LAKE
Kamsack
05MD004
KAMSACK RESERVOIR
River
THEODORE RESERVOIR
05MB009
River
Yorkton Creek
Springside
05MB005
Yorkton
Willow Brook
WILLOWBROOK DIVERSION
Crescent Creek
Melville
River
Roblin
Shell
River
LAKE OF THE PRAIRIES
05MD009
05MD005
SHELLMOUTH DAM
05ME001
SCALE
10
0
10
20
30
40
Kilometres

The Assiniboine River, as we now know it, originates in the southeastern region of Porcupine Provincial Forest, some 54 kilometres northwest from the Town of Preeceville in northeast central Saskatchewan. The river flows in a south easterly direction for some 147 kilometres before being joined by its major tributary, the Whitesand River near Kamsack, Saskatchewan. The river then continues in a south easterly direction for some 45 kilometres before crossing into Manitoba. Shellmouth dam, located on the Assiniboine River about 51 kilometres downstream from the interprovincial boundary forms a lake 56 kilometres long and backs water up into Saskatchewan. Immediately above Shellmouth dam, the Assiniboine River also joins the Shell River in Manitoba. It then flows for some 68 kilometres to where it joins the Qu'Appelle River near St. Lazare, Manitoba.

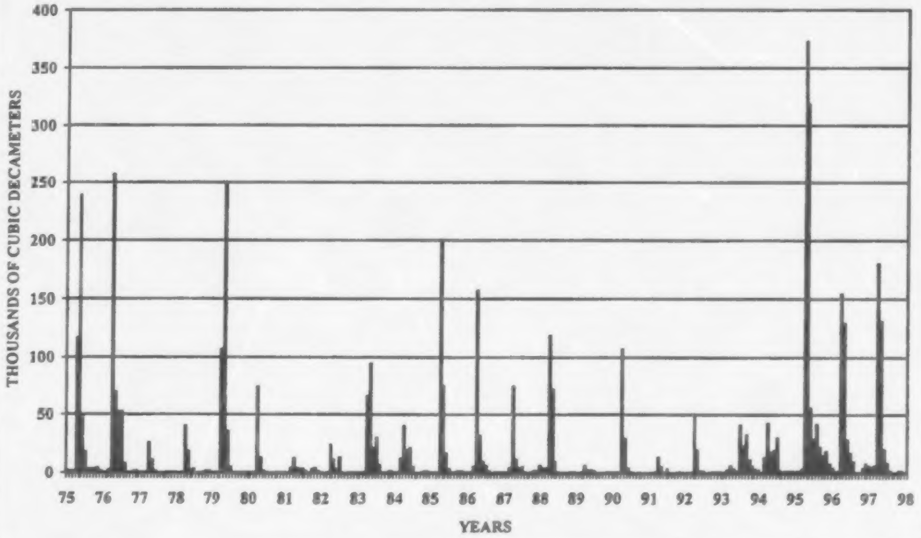
Hydrology

The Assiniboine River at Kamsack (00SA05MD004) is used as the PPWB Interprovincial station on this river. A natural flow study was conducted by the Hydrology Division of PFRA under the direction of the Prairie Provinces Water Board to estimate natural streamflow in the Assiniboine River Basin tributary at the Saskatchewan-Manitoba boundary. The study was entitled "Assiniboine River at Saskatchewan-Manitoba Boundary - Natural Flow - November 1980 - PPWB Report No.The mean annual streamflow estimate based on streamflow from 1957 to 1993 inclusive was 159 418 dam^3. The average monthly flows for the period 1975 to 1997 are as shown in Figure 2. The average annual water use, at the present level of use, would represent only 2.7% of this value, thus present water use in the Assiniboine River Basin represents only 5.5% of Saskatchewan's 50 percent share of the average annual natural flow.

Land Use and Demography

The Assiniboine River Basin has been developed almost completely for agricultural purposes. The land is located in the transition area between black soils and grey-wooded podzolic soils, and has been developed for dry land purposes. There is very little industry and only limited recreational uses made at some points in the basin.

FIGURE 2. ASSINIBOINE RIVER AT KAMSACK
MONTHLY RECORDED FLOW



Because the land in many areas is poorly drained, it is a good breeding ground for waterfowl. Ducks Unlimited have taken advantage of these conditions in several areas in the Assiniboine River Basin to develop projects to enhance the natural sloughs ensuring the propagation of ducks and other water-based wildlife. Good Spirit Lake, in the non-contributing part of the basin has been developed for recreational purposes and a provincial park is located on the south part of the lake.

The first inhabitants of this area were Cree and Assiniboine Indians. When the Europeans came to the area, trappers and traders usually went either farther north to the Saskatchewan River system or south along the more easily traveled Qu'Appelle and Pipestone Rivers. At the end of the last century, however, immigrant migration started, and in subsequent years the basin received many immigrants from Europe. Lands were cleared and, since then, the region has remained primarily agricultural. The larger centres of Yorkton, Canora and Kamsack have some relatively small industries designed primarily to serve the local agricultural markets. The population in the Saskatchewan portion of the basin is 53 613 (1991 Census) and the Manitoba portion is 110 831. The population according to the 1991 census shows Yorkton 15 315, Canora 2381 and Kamsack 2323.

Economic Base

The Assiniboine River Basin has had little, if any, economic growth in the past several years. The basins overall population has been slowly decreasing and its agricultural income has remained relatively stable. Improved farm lands have increased slightly over the years and the livestock population (around 4 000) has remained relatively stable. An active wetland drainage program by farmers has been ongoing for years to improve the agricultural farmland. This has been a contentious issue for years in the basin.

Most attempts to develop the industrial base, particularly at Yorkton, have met with limited success. The basin has no strong industrial base and only small quantities of water are required to supply the present industries.

Water Use & Concerns

Six major water storage projects are located within the effective drainage area of the Saskatchewan portion of the Assiniboine Basin. These include Newburn Lake, Kamsack Reservoir, Sturgis Weir, Canora Reservoir, Theodore Reservoir and Willowbrook Diversion.

Uses from these projects have been minor with some of the larger uses occurring at the Willowbrook diversion where a channel has been built to carry flows eastward to Roussay and York Lakes, for Ducks Unlimited and other recreational purposes. These diverted flows do not usually return to the Whitesand River, although a small return flow may occur in some wet years. A field program was undertaken in the summer of 1979 as part of the PFRA Hydrology Division study to identify all man-made water storage sites located within the effective drainage area of the Assiniboine River Basin in Saskatchewan. Several of these projects have since washed out. Approximately 11 500 hectares of land were irrigated in the basin during 1986. Water use for irrigation was 14 153 dam^3. Individual water use (1877 dam^3) in the basin in 1991 was only 1.5% of the average annual recorded flow at Kamsack.

In past years water quality concerns in the Assiniboine River related to elevated coliform counts as a result of seepage from the Town of Kamsack's sewage lagoons. The lagoons were repaired in the late 1970's and coliform counts are now not a problem. Periodic exceedances of the PPWB Objectives for manganese, total phosphorus and dissolved oxygen have occurred.

WATER QUALITY DATA ANALYSIS

Water Quality Data

Assiniboine River water quality samples were collected approximately one mile south of Kamsack off highway #8 bridge near the Saskatchewan/Manitoba boundary (00SA05MD0002) for the period April, 1974 to December, 1998. The Assiniboine River sampling location is shown in Figure 1. The location was sampled whenever possible on a monthly basis, but on several occasions during ice breakup, samples could not be obtained. A list of the 98 water quality variables collected from the sampling site is shown in Table 2. Key variables, marked with an asterisk were selected (26 variables), for interpretative purposes, to provide a general characterization of the biological, physical and chemical aspects of the Assiniboine River water quality. These samples were collected and analysed by Environment Canada according to standard methods.

The occurrence of missing data, detection limits and the presence of observations below the detection limits must be studied in order to interpret the trend analysis results. This information and the individual sample results are shown in Appendix 1.

Aldrin
Alkalinity, phenol.
Alkalinity, total
Aluminum, dissolved
Aluminum, ext.
Arsenic, diss.
Atrazine
Barban
Barium, Total
BHC-alpha *
BHC-gamma(Lindane)
Bicarbonate, calc.
Boron, diss.*
Bromoxynil
Cadmium, total
Calcium, diss.*
Carbon, diss., organic
Carbon, organic, particulate
Carbonate, calc.
Chlordane-Alpha
Chlordane-gamma
Chloride, diss.*
Chlorophyll A
Chromium, total
Cobalt, total
Coliforms, fecal*
Coliforms, total
Color, true
Copper, total*
Cyanide, total
P.P.-DDD
P.P.-DDE
O.P.-DDT
P.P.-DDT
Diallate
Dicamba
Diclofop-methyl
Dieldrin
Endovan
Endosulfan-alpha
Endosulfan-beta
Endrin
Fluoride, diss.
Free CO$_2$
Hardness, non-carbonate
Hardness, total CaCO
Heptachlor
Heptachlor, epoxide
Hexachloro-benzene
Hydroxide, calc.
Iron, diss.*
Lead, total*
Manganese, diss.*
Magnesium, diss.
MCPA
MCPB
Mercury, total*
P.P-methoxychlor
Mirex
Nickel, total*
Nitrogen,diss.,NO$_3$+NO$_2$*
Nitrogen, particulate
Nitrogen, total Ammonia*
Nitrogen, total, calc.*
Nitrogen, total, diss.
Oxygen, diss., (DO)*
PCB, Aroclor 1242
PCB, Aroclor 1254
PCB, Aroclor 1260
PCB, Aroclor total
pH *
Phosphorus Ortho as P
Phosphorus, part. calc.
Phosphorus, total diss.
Phosphorus, total as P *
Picloram (Tordon)
Potassium, diss.
Residue,fixed,non-filterable
Residue, non-filterable*
Selenium, diss.
Silica, reactive
Silver
Sodium, percent
Sodium, diss.*
Solids,total diss.,calc.*
Specific Conductance*
Sulphate, diss.*
Temperature
Triallate
Trifluralin
Turbidity*
Vanadium, total
Zinc, total*
2,3,6-TBA
2,4-D*
2,4-DB
2,4-DP
2,4,5-T*

A monthly sample may not be collected at certain sites because of poor access to the sampling location. This generally occurred during spring or fall. Missing data in the data base was identified by a -99.9900 value. Values below the detection limits are also reported as -99.9900 for trend analysis purposes. The statistical trend tests do not consider the -99.9900 values in the calculations.

Assiniboine River water quality data were reviewed to identify specific spill events that had occurred during the period of record. Spill events were verified using the PPWB Contingency Plan reports and PPWB agency data upstream from the monitoring sites. There were no spills on the Assiniboine River during the collection period and hence no samples were removed prior to trend analysis.

Any change in analytical method must also be considered in interpreting the trend results. A change in methods can influence data results especially in those cases where detection limits change. The data base has been reviewed to identify analytical method changes over the period of record. In most cases the data results are completely compatible and the detection limits remained unchanged. There were, however, some method changes which did influence the results of the trend analysis. Boron and several metals analysis such as iron, copper, nickel, mercury and lead, experienced method changes as well as detection limit changes..

Unusual laboratory results, during the verification process, are checked for proper ion balance to ensure dissolved forms are less than total and that laboratory results correspond well to field results.

Statistical Methods Applied to the Entire Data Base

Water quality data for the Assiniboine River have a monthly sampling frequency and a record length of approximately 17 to 20 years. Some data is missing and for some variables, such as trace metals and pesticides, there are a number of observations below the analytical detection limit. Because the period of record is of substantial length, serial correlation is likely not present.

As recommended (Dr. El-Shaarawi, S.R. Esterby et al, 1991), the PPWB conducted non-parametric tests such, as the Kendall Tau and Spearman Trend Tests, to determine long-term trends in water quality at the

PPWB monitoring sites. Non-parametric techniques were used because they are suited to non-normality and extreme values and their ease in addressing values below the detection limit. In addition, both the Spearmans Rank Correlation Coefficient and the Kendall Tau compare favourably to the parametric alternative in that they both have a asymptotic relative efficiency of about .98 relative to β (Conover 1980). The Spearman Rank Correlation Coefficient (Ps) is slightly more powerful than the Kendall's Tau, but the Kendall Tau converges to normality faster (Van Belle and Hughes 1984). In these non-parametric tests the values below the detection limit are treated as ties, hence the limitations on the usefulness of the techniques are due to the total number of less than values.

To determine the homogeneity of trend, as well as the test for long-term trends, the Van Belle tests were run. If homogeneity exists, then the measure of average trend, such as the Seasonal Kendall Tau can be used, otherwise it is recommended that tests with individual months be used. The measure of average trend used in the Seasonal Kendall Tau test is actually the weighted average of the Tau's in the individual months (El-Shaarawi 1991).

One assumes that the data are not serial dependent when running non-parametric procedures. The set of monthly values of each water quality variability over the 17 to 20-year record appears to satisfy the assumption of independence and thus the assumptions are generally satisfied when the trend test is applied to observations from the same month. Therefore, the proposed Modified Seasonal Kendall Tau (Hirsch and Slack 1984) which uses an estimate of the covariance between months was used. Hirsch and Slack have shown that the modified Seasonal Kendall Tau performs well for water quality data bases that exceed ten years in record.

The non-parametric tests were therefore applied to yearly data to determine long-term trends reported by the Water Quality Technical Committee. The non-parametric tests were applied on each month to assist the PPWB in identifying potential causes of water quality trends on these streams. For instance, if a positive trend was evident over the period of record and that trend was also significant during the time that municipal discharges occur then the results may shed some insight as to the potential cause of the trend.

Non-parametric methods applied to yearly data for the purpose of this report were the Seasonal Kendall, the modified Seasonal Kendall Tau, (to remove flow effects), the Van Belle statistics (to determine a change in sign over the period of record), the Kendall Coefficient, the Spearman Coefficient, the Seasonal Lower and Upper Confidence Interval, the Sen Lower and Sen Upper Confidence Interval and the Seasonal Estimate of the Slope. A further description and the formulas for these statistics are in Dr. El-Shaarawi's report to the PPWB entitled "Trend Assessment Techniques: Application to Prairie Provinces Water Board Water Quality Data Set - March 1991".

To assist in determining a significant trend the Sen Lower and Sen Upper Confidence Intervals were performed. If both confidence intervals are negative or positive then there is a significant trend in the data base. An asterisk following the trend test result (see Appendix 2) indicates that the result is significant at the 5% level (i.e. 95% confident of the result). Appendix 3 contains a description of statistical terms.

Statistical Methods Applied on a Monthly Basis

Non-parametric tests applied on a monthly basis were used to identify whether specific trends over the period of record are a result of certain occurrences during a particular time of year. These results may be useful in attempting to identify the cause of a specific significant positive trend in the variable at the monitoring site. A variety of tests were run on data results for each month during the period of record. These tests include the Mann and Kendall statistic coefficient, the Spearman Rank Correlation statistic coefficient, the Sen Lower and Upper Confidence Interval and the Sen Estimate of Slope. The statistical formulas and a description of the tests are discussed in Dr. El-Shaarawi's report entitled" Trend Assessment Techniques: Application to Prairie Provinces Water Board Water Quality Data Set - March 1991".

Non-parametric trend test results applied on a monthly and annual basis are shown in Appendix 2. Results which were significant at the 95% confidence level are denoted with an asterisk.

Plots

Time series plots are informative at all stages of analysis and are essential in trend analysis interpretation. These plots are useful in showing the strength of seasonal cycles, extreme observations and gaps in the data base. The Lowess smooth curve and least squares best fit line are also provided on the time series graphs. The Lowess smooth curve uses the locally weighted regression scatter plot smoothing method, a statistical method suitable for fitting a line to a set of points on a scatter plot. A complete description of the Lowess smooth curve method is described in the report entitled, "Graphical Methods of Data Analysis" (Wadsworth International Group and Duxbury Press, 1983), by John A. Chambers, William S. Cleveland, Beat Kleiner and Paul A. Tukey. The Lowess smooth curve created for the time series plots uses a smoothing factor of 0.5 to create the smooth line. The Lowess smooth line can give an indication as to whether the trend is constant or changing over time.

Each time series graph has a least squares best fit line. The least squares fit equation is the equation that minimizes the sum of squares of deviations of the observed y values from the predicted y values. The fitted line uses the following equation to fit the model to the data:

$$y = A + B * X$$

Where A is the slope and B is the intercept and X is the order of the data.

Some goodness of fit statistics are also included with each least squares best fit line. These statistics include the Significance of Slope and the r value. R value is determined from r^2 which is the multiple correlation coefficient. The least squares best fit line was added to each of the time series graphs to create a fitted function to examine how closely the model conforms to the data.

Time series graphs with the squares best fit and Significance of Slope statistics and Lowess smooth curves are not as powerful a test as the Kendall Tau or the Spearman Coefficient statistics but aid in the overall interpretation of water quality trends. It is assumed that if the significance of the slope is smaller than or equal to 0.05, the slope is considered significant.

RESULTS AND DISCUSSION

Water Quality Trends in the Assiniboine River

General

Long-term non-parametric trend analysis results for all variables in the Assiniboine River are shown in Appendix 2. Discussion in this section of the report covers variables that show a significant long-term trend or those variables that are of potential concern because present levels exceed the 1991 PPWB Water Quality Objectives established for the Assiniboine River at the interprovincial boundary.

The time series graphs with Lowess smooth curves and least squares best fit lines, prepared for variables, are either included in this section or in Appendix 3.

Non-parametric trend results indicate that there were no long-term trends in TDS, conductivity (field), turbidity nitrate and nitrite (NO3 + NO2), ammonia (total), total nitrogen, PH(field), dissolved oxygen (DO), NFR, Sodium (diss), phosphorus (total), sulphate (diss.), chloride (diss), calcium (diss.) and manganese (diss.), and zinc (total) in the Assiniboine River at the Saskatchewan-Manitoba boundary. Since these constituents with the exception of dissolved oxygen, phosphorus (total) and manganese (diss.) have no PPWB objective or are presently at levels below the PPWB objectives, and are not presently increasing, they are not expected to be a concern in the Assiniboine River.

Constituents such as dissolved oxygen, phosphorus (total) and manganese (diss.) in the Assiniboine River did not reveal a long-term trend but because they occasionally exceed the PPWB Water Quality Objective they are constituents of potential concern and are discussed further in this section.

A discussion of those variables with a significant long-term trend are also discussed in the following section.

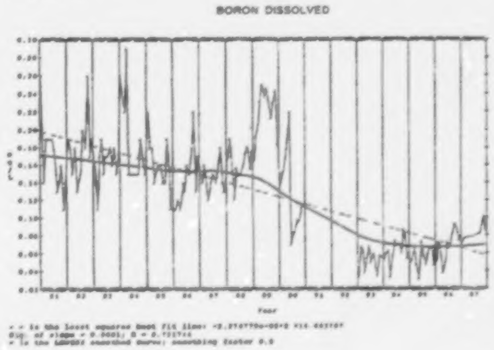
Boron Dissolved

Non-parametric trend tests, the Seasonal Kendall Tau and the Van Belle trend statistics indicate, at a 5% significance level, that there is a slight negative trend in boron dissolved concentrations over the period 1981to 1997. This negative trend is confirmed by the Seasonal Kendall, Modified Seasonal Kendall and the Van Belle non-parametric trend test (see results Appendix 2.)

A series of trend statistics including the Mann and Kendall statistics and the Spearman Rank Correlation Coefficient were computed for each month (Appendix 2). The monthly trend statistics, such as the Mann and Kendall Tau and the Spearman statistic for all months suggest a ($P \leq 0.05$) decrease in boron dissolved levels. The negative Sen Lower Confidence Intervals and the negative Sen Upper Confidence Intervals substantiate the significant negative trend for all months.

The time series graph in Figure 3 shows the variability in boron concentrations over time in the Assiniboine River. Generally, boron concentrations increased substantially during the winter period and are at their lowest during the spring and summer months. The Significance of Slope statistic for the least squares best fit line (0.0001) supports the overall non-parametric trend results. The Lowess smooth curve with a factor of 0.5 suggests that there was a slight decrease in boron levels from 1981 to 1990, and an abrupt reduction in concentration from 1990 to 1993. In 1993 the analytical method changed to method, code 05108G which may be less sensitive to interference from other compounds reflecting lower concentrations than previous methods.

FIGURE 3



In conclusion the significant negative trend identified by the non-parametric trend analysis is probably not a reflection of a change in water quality but rather due to the analytical method change in 1993.

Boron dissolved concentrations in the Assiniboine River at the Saskatchewan-Manitoba boundary range from .031 to 0.29 mg/L. Boron levels are well below the PPWB objective (2.0 mg/L) for this variable. With no further development on the river or increased use of river water, boron concentrations are unlikely to have any effect on downstream users in the basin in the near future.

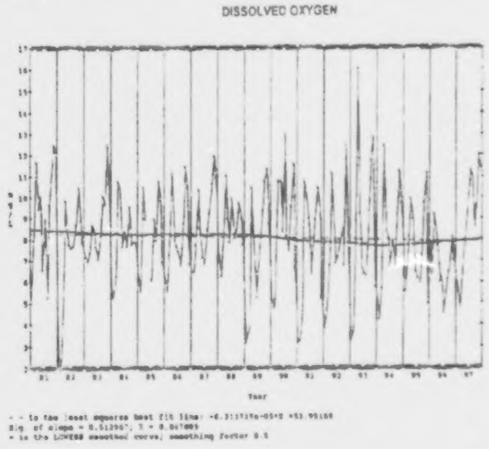
Dissolved Oxygen

The Seasonal Kendall Tau and Modified Seasonal Kendall Tau, as well as, the Van Belle trend statistics indicate, at a 5% significance level, that there is no trend in dissolved oxygen concentrations over the period 1981 to 1997.

The Mann and Kendall statistics and the Spearman Rank Correlation Coefficient were computed for each month (Appendix 2). The monthly trend statistics, such as the Mann and Kendall Tau and Spearman results for September suggests a ($P \leq 0.05$) decrease in dissolved oxygen. A negative Sen Lower Confidence Interval and a negative Sen Upper Confidence Interval substantiate a possible negative trend for the month of September.

The time series graph in Figure 4. shows the high variability in dissolved oxygen levels in the Assiniboine River from the period 1981 to 1997. Generally, dissolved oxygen levels increased substantially during the spring and fall and are at their lowest during the winter months.

FIGURE 4



The Significance of Slope statistic (0.5129) does not suggests a significant change in dissolved oxygen levels. The Lowess smooth curve with a factor of 0.5 shows only a slight decrease in dissolved oxygen concentrations from 1981 to 1997.

Dissolved oxygen concentrations in the Assiniboine River at the Saskatchewan-Manitoba boundary for the period 1974 to 1997 range from 2.2 to 16.1 mg/L with several values below the PPWB objective of 6.0 mg/L. Although there is no significant long-term trend in dissolved oxygen concentrations, the trend tests suggest a possible but slight decrease in dissolved oxygen concentrations in the month of September. With some dissolved oxygen concentrations below the objective there is some concern, assuming some future development in the basin, on instream users such as fish and aquatic life.

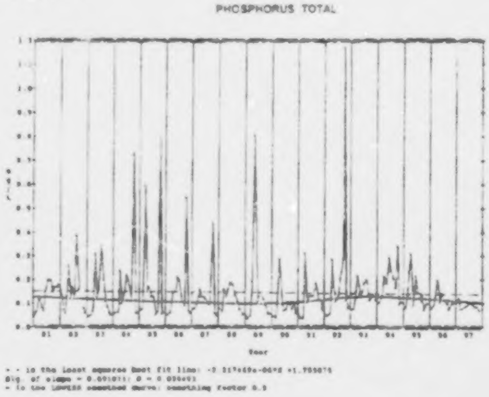
Phosphorus Total

For the period 1981 to 1997 non-parametric statistics, at a 5% significant level, indicate that total phosphorus concentrations in the river have not changed. The Seasonal Kendall and the Modified Seasonal Kendall and the Van Belle trend tests reveal a slight increase over time but not a significant increase. The Seasonal Lower Confidence Interval (-.0003) and the Seasonal Upper Confidence Interval (.0019) also do not suggest any significant change.

The series of trend statistics conducted for each month show that total phosphorus values in some months are slightly increasing and other months are slightly decreasing but that no month has a significant trend. The negative Sen Lower Confidence Interval and the positive Sen Upper Confidence Interval for these months also suggest there is no significant positive or negative trend in total phosphorus concentrations.

The time series graph (Figure 5) suggests a strong Seasonality in total phosphorus values with the Spring

FIGURE 5



and Fall months experiencing high concentrations and the Winter months experiencing low total phosphorus concentrations. The Significance of Slope statistic (.69101) suggests there is no significant trend and supports the Kendall Tau, Modified Kendall Tau, and Van Belle trend results. The Lowess smooth curve also shows no noticeable trend in total phosphorus concentrations from the 1981 to 1997.

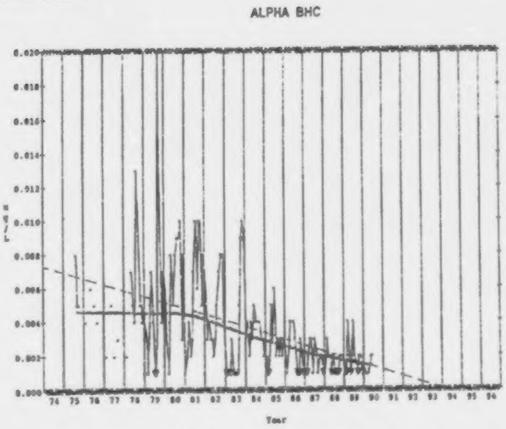
Total phosphorus concentrations in the Assiniboine River range from .03 mg/L to 1.17 mg/L. The highest concentrations occur in the spring at runoff time and in the fall during the time when the municipalities discharge from their sewage lagoons. Most total phosphorus concentrations exceed the PPWB Water Quality Objective for total phosphorus (0.05 mg/L). Saskatchewan Environment and Public Safety, Water Quality Branch conducted a study in 1991 on the " influence of Kamsack Effluent Discharges". The study determined that elevated levels of total phosphorus were detected at the PPWB station near Kamsack during the release and beyond in the fall. Total phosphorus increased from less than .3 mg/L to greater than .5 mg/L.

The PPWB objective for total phosphorus in the Assiniboine River is 0.05 mg/L. This objective is exceeded much of the time at the Assiniboine River near Kamsack site. With elevated levels in the Assiniboine below Kamsack there is a potential concern regarding increased aquatic weed growth in the river. A provincial study recommendation was made with respect to the department examining opportunities for extended treatment of sewage to improve the quality of the Kamsack sewage discharges.

Alpha BHC

The Seasonal Kendall Tau, the Modified Seasonal Kendall Tau and the Van Belle trend statistics over the entire period of record (1975 to 1990) indicate that concentrations of Alpha BHC are decreasing at the 5% significance level, in the Assiniboine River. The series of monthly trend statistics were computed including the Mann and Kendall Tau and the Spearman Rank Correlation Coefficient (Ps). These tests show a significant ($P \leq 0.05$) decreasing trend in Alpha for the months of January, April, May, August, September, October, November and December. Environment Canada also found that Alpha BHC concentrations, and annual deletion frequency decrease significantly in the Assiniboine River during the period 1975 to 1994 (R.O. Crosley et al).

FIGURE 6



- - is the least squares best fit line: -0.941688e-07*X +0.723734
Sig. of slope = 0.0001; R = 0.489352
= is the LOWESS smoothed curve; smoothing factor 0.5

The time series graph (Figure 6.) shows that there is a high level of variability in Alpha BHC throughout the year. Some high peaks appear in the spring while others appear in the fall. Positive alpha BHC hits may be related more to precipitation events than anything else. The least squares best fit line and the Significance of Slope (.0001) also support the Kendall Tau trend results of a significant negative trend at a 5% significant level. The Lowess smooth curve, with a factor of 0.5, suggests a consistent decrease in Alpha BHC levels in the Assiniboine River over time. This decreasing trend may be related to reduced global use of the pesticide in the basin.

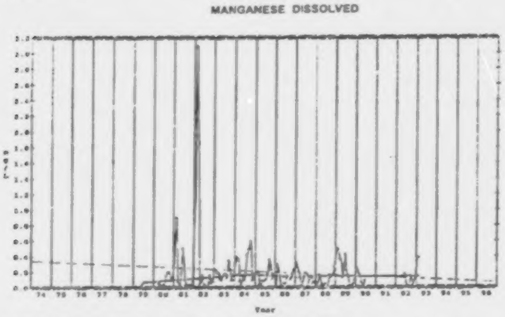
Alpha BHC concentrations in the Assiniboine River range from less than .001 μg/L to .020 μg/L with a 90 percentile level of .008 μg/L. No PPWB objective has been established for Alpha BHC in the Assiniboine River. With existing concentrations of Alpha BHC at very low levels and with a significant decreasing trend in Alpha BHC concentrations, there is little chance that this variable will have an effect on water uses in the Assiniboine basin.

Manganese Dissolved

The Seasonal Kendall Tau, the Modified Seasonal Kendall Tau and the Van Belle Trend statistics indicate no significant trend in manganese in the Assiniboine River for the period 1979 to 1993. The negative Seasonal Lower Confidence Interval and the positive Seasonal Upper Confidence Interval also suggest that there is no trend in manganese dissolved concentrations in the Assiniboine River for the entire period of record.

A series of trend statistics including the Mann and Kendall Tau and the Spearman Rank Correlation Coefficient were computed for each month and the results indicate no month displays any significant trend. A negative Sen Lower Confidence Interval and a positive Sen Upper Confidence Interval for each month also confirms that no trends exist.

FIGURE 7



- - is the least squares best fit line: -3.[illegible]e-05*X +21.[illegible]
Sig. of slope = 0.16122; R = 0.133110
- is the LOWESS smoothed curve; smoothing factor 0.5

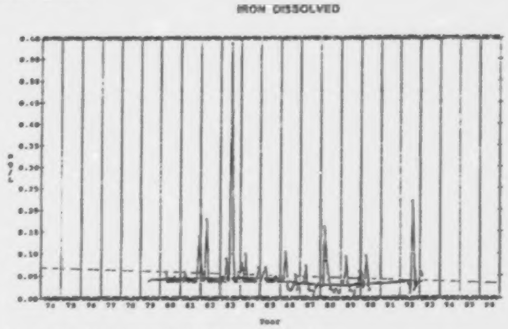
The time series graph in Figure 7 along with the least squares best fit line and the Significant of Slope statistics (0.16122) suggest no significant change in manganese concentrations for the period 1980 to 1993. Manganese dissolved concentrations in the Assiniboine River range from less than 0.01 mg/L to 3.1 mg/L with a median concentration of 0.125 mg/L. The PPWB Water Quality Objective for manganese dissolved in the Assiniboine River is 0.05 mg/L. This objective is exceeded on several occasions and may be of concern to domestic water supplies downstream in the basin.

Iron Dissolved

Non-parametric long-term trend analysis tests including the Seasonal Kendall Tau, Modified Seasonal Kendall Tau, and Van Belle Trend statistics show a negative trend in iron dissolved concentrations, at the 5% significance level, in the Assiniboine River at the interprovincial boundary from the period 1979 to 1993. The negative trend is slight as the change as measured by the seasonal estimate of slope is -0.0009 mg/l per year.

Seasonal trend statistics computed for each month showed a significant negative trend for iron for the months of May and June.

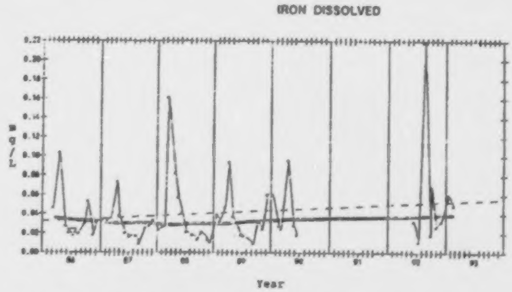
FIGURE 8



- - is the least squares best fit line: -[illegible]e-06*X +1.[illegible]
Sig. of slope = 0.274712; R = 0.089762
- is the LOWESS smoothed curve; smoothing factor 0.5

The time series graph in Figure 8, along with the least squares best fit line and the Significance of Slopes statistic (0.2747) show no significant trend in iron dissolved levels, at a 5% significance level, in the Assiniboine River. A close look at the graph reveals there was a method change in 1986 that may have influenced the graphs slope and non-parametric trend statistics. This method change decreased the detection limit from less than .04 mg/L to less than .007 mg/L. Time series graphs, least squares best fit lines and Significance of Slope statistics were rerun for the period 1986 to 1993 (Figure 9.). This new graph suggests that iron concentrations are not decreasing at a significant rate (Significance of Slope 0.2100) but are increasing slightly. The results of the non-parametric trend analysis may have been influenced by the change in detection limit.

FIGURE 9



- - is the least squares best fit line: 8.105602e-06*X -5.844595
Sig. of slope = 0.210042; R = 0.164173
- is the LOWESS smoothed curve; smoothing factor 0.5

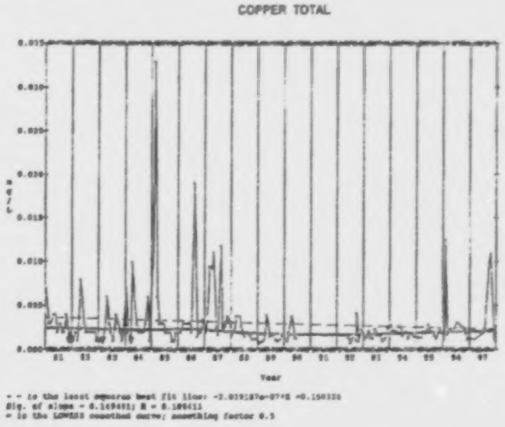
Iron dissolved concentrations in the Assiniboine River at the Saskatchewan-Manitoba boundary range from less than 0.02 mg/L to 0.59 mg/L with a median concentration of 0.04 mg/L. Because there is no significant trend in iron concentrations and because the PPWB Water Quality Objective for iron dissolved (0.3 mg/L) has only been exceeded once in the last thirteen years it is unlikely that iron levels will affect downstream users in the Assiniboine River basin, in the near future.

Copper Total

Trend analysis results including the Seasonal Kendall Tau and the Van Belle Trend statistics, on data for the period 1981 to 1997, indicate that copper total concentrations are decreasing at the 5% significant level in the Assiniboine River at the interprovincial boundary.

Seasonal trend statistics computed for each month show a significant negative trend in copper levels for the months of April and May.

FIGURE 10



The time series graph in Figure 10, along with the least squares best fit line and the Significance of Slopes statistic (0.1495) does not indicate a significant negative trend at the 95 percent level. The Lowess smooth curve suggests that copper concentrations were relatively stable from 1981 to 1997. Further investigation of the data base revealed that the method for copper total also changed in 1993 and in 1994 which accounted for the negative trend results. There is therefore no significant change in water quality copper concentrations in the Assiniboine River

Copper total concentrations in the Assiniboine River at the Saskatchewan-Manitoba boundary range from less than 0.0007 mg/L to 0.033 mg/L. The PPWB objective for copper total in the Assiniboine River is 0.01 mg/l which was only exceeded a few times in the last decade. With a no trend in copper total concentrations and with only two values exceeding the objective since 1987 it is likely that downstream uses will not be affected by copper concentrations in the Assiniboine River.

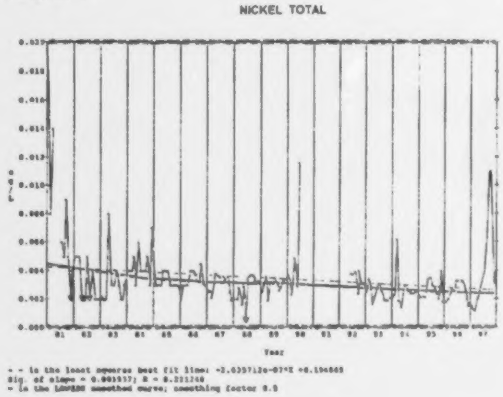
Nickel Total

The Seasonal Kendall Tau, the modified Seasonal Kendall Tau and the Van Belle trend statistics over the period (1981 to 1997) indicate that concentrations of nickel total are decreasing at a 5% significance level in the river. The seasonal estimation of slope was -0.0001.

The Mann and Kendall Tau and the Spearman Rank Correlation Coefficient were computed for each month and the months of January, February, March, April, May and July showed a significant ($P<0.05$) negative trend.

The time series graph in Figure 11 along with the least squares best fit line and the Significance of Slope statistics (0.0035) support the Kendall Tau results of a significant negative trend at a 5% significance level. The Lowess smooth curve with a factor of 0.5 also shows a slight decrease in nickel total from 1981 to 1997.

FIGURE 11



Nickel total concentrations in the Assiniboine River range from less than 0.0005 mg/L to 0.019 mg/L, with a median concentration of 0.0033 mg/L. The PPWB Water Quality Objective for nickel total has been established at 0.10 mg/L in the Assiniboine River. All nickel total concentrations are well below this objective. Nickel total concentrations are not expected to be a concern in the Assiniboine River , in the near future, since they are decreasing significantly and are presently at low levels.

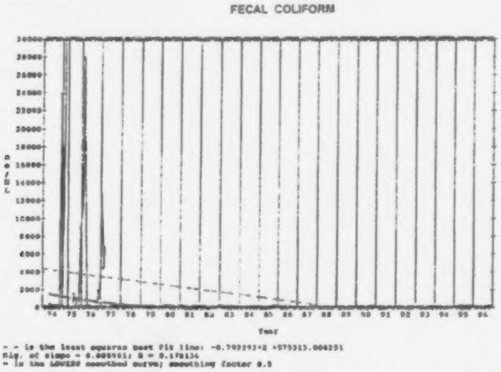
Coliform Fecal

The Seasonal Kendall Tau and the Van Belle trend statistics over the period of record (1974 to 1993) indicate that concentrations of fecal coliform are increasing at a 5% significance level in the river.

Trend statistics including the Mann and Kendall Tau and the Spearman Rank Correlation Coefficient were computed for each month but no specific month showed a significant (P<0.05) negative trend.

The time series graph in Figure 12 along with the least squares best fit line and the Significance of Slope statistics (0.0058) supports the Kendall Tau results of a significant negative trend at a 5% significance level. The Lowess smooth curve with a factor of 0.5 shows a decrease in fecal coliforms from 1974 to 1993.

FIGURE 12



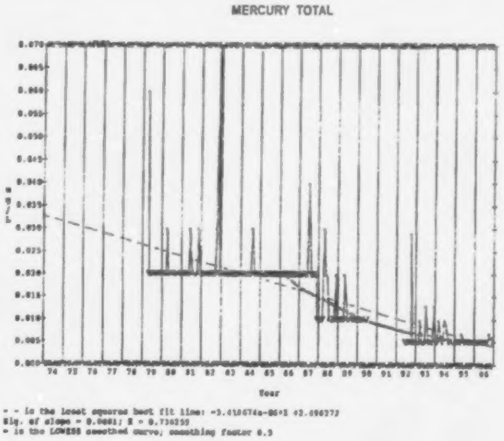
Fecal coliform concentrations in the Assiniboine River range from less than 2 counts per 100 ml to 15000 counts per 100 ml, with a median concentration of 10 counts per 100 ml. The PPWB Water Quality Objective for fecal coliforms in the Assiniboine River is 100 counts per 100 ml. This objective was exceeded on occasion in the early seventy's but with repairs to the Kamsack sewage lagoon the objective has not been exceeded in the last twenty years. With decreasing fecal coliform concentrations in the Assiniboine River and the PPWB objective not being exceeded in the past two decades, fecal coliform levels are not expected to be a potential concern in the Assiniboine River, in the near future.

Mercury Total

Long-term trend analysis statistics for mercury total in the Assiniboine River including the Seasonal Kendall Tau, Modified Seasonal Kendall Tau and the Van Belle trend statistics over the period of record (1979 to 1993) suggest that concentrations of total mercury are decreasing at the 5% significance level in the river. Total mercury appears to be decreasing at a rate of -0.0011 μg/L/yr.

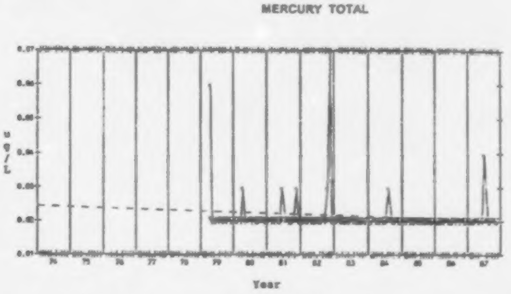
Trend statistics including the Mann and Kendall Tau and the Spearmans Rank Correlation Coefficient were computed for each month. Total mercury concentrations for the months of January, February, March, April, May, June, August, November and December showed a significant ($P \leq .05$) deceasing trend. Insufficient information was available to calculate Sen Upper Confidence Intervals for the months.

FIGURE 13



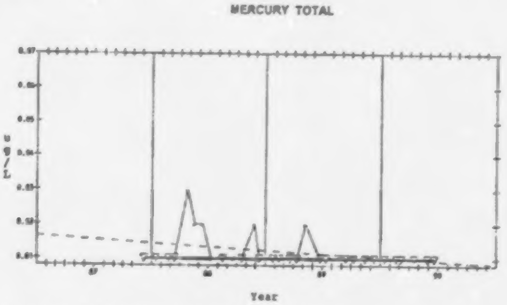
The time series graph in Figure 13 for the period 1974 to 1996, along with the least squares best fit line and the Significance of Slope statistic (0.0001) also suggests a negative trend at the 5% significance level for total mercury. It is evident, however, from the time series graph that the method of analysis for mercury changed in the winter of 1987 and spring of 1992 as the detection limit changed accordingly. The detection limit for mercury dropped from <0.02 μg/L to <0.01 μg/L and to <0.005 μg/L respectively. Time series graphs, least squares best fit lines and the Significance of Slope for only one method (Figures 14,15 and 16) was computed to remove the influence of a method change. The results show a slight decrease but no significant trend in total mercury concentrations when the tests are run on data by only one analytical method. The new Significance of Slope statistics (0.2602, 0.0845 and .2066) do not indicate a significant trend in mercury concentrations for the periods 1979 to 1987 or 1988 to 1990 or 1992 to 1997. It would appear that the Seasonal Kendall Tau and Van Belle Trend statistics from the overall data were influenced by a change in analytical method for mercury.

FIGURE 14


MERCURY TOTAL

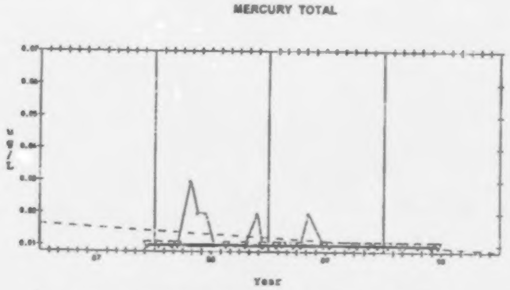
- - is the least squares best fit line: -8.259627e-07*X +0.619618
Sig. of slope = 0.260292; R = 0.111386
= is the LOWESS smoothed curve; smoothing factor 0.5

FIGURE 15


MERCURY TOTAL

- - is the least squares best fit line: -5.541387e-06*X +4.035984
Sig. of slope = 0.084568; R = 0.320154
= is the LOWESS smoothed curve; smoothing factor 0.5

FIGURE 16


MERCURY TOTAL

- - is the least squares best fit line: -5.561357e-06*X +4.035984
Sig. of slope = 0.084568; R = 0.320154
= is the LOWESS smoothed curve; smoothing factor 0.5

In conclusion, the Seasonal Kendall Tau and the Van Belle trend statistics showed a false negative trend in mercury concentrations as a result of the change in detection limit. There is no trend in mercury concentrations in the Assiniboine River for the period 1974 to 1993 or from 1993 to 1997.

Total mercury concentrations in the Assiniboine River ranged from <.005 μg/L to 0.07 μg/L with a 90 percentile concentration of <0.02 μg/L. No PPWB Water Quality Objective has been established for mercury in water for the Assiniboine River. However, an objective has been established for mercury in fish tissue (0.5 μg/g). The CCME guideline for total mercury in water is 0.1 μg/L to protect aquatic life. With the historical data indicating no trend in mercury and with no values during the eighteen year period exceeding the CCME guideline of 0.1 μg/L, it is not anticipated that mercury concentrations in the Assiniboine River will have much of an affect on downstream uses.

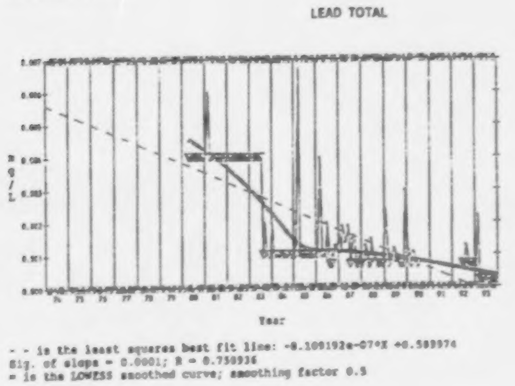
Lead Total

The long-term trend analysis statistics for lead total for the period 1980 to 1993, (Appendix 2) which include the Seasonal Kendall Tau, the Modified Seasonal Kendall Tau, and Van Belle trend statistics suggest that lead is decreasing at the 5% significance level in the Assiniboine River. The negative Seasonal Confidence Intervals also suggest that lead total is decreasing in concentration.

A series of monthly trend statistics including the Mann and Kendall Tau and Spearman Rank Correlation Coefficient were also computed and they suggest a decrease in total lead concentrations for all months except February.

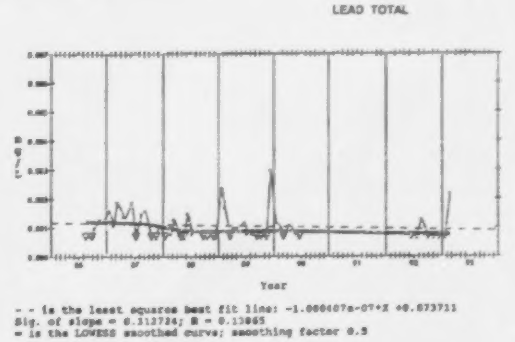
The time series graph in Figure 17, along with the least squares best fit line and Significant of Slope statistic (0.0001) also support the hypothesis that lead total is decreasing in the Assiniboine River over time. A closer look, however, at the time series graph shows that the analytical method for lead total changed significantly in 1983 and 1986. The detection limit for total lead dropped from <0.004 mg/L to <0.001 mg/L then to <0.0007 mg/L.

FIGURE 17



A time series graph for the last method (1986-93), along with the least squares best fit line and the Significance of Slope statistics were prepared. This graph is shown in Figure 18.

FIGURE 18



The least squares best fit line and Significance of Slope statistic (0.3127) for this method indicates that there is no significant trend in total lead concentrations in the Assiniboine River.

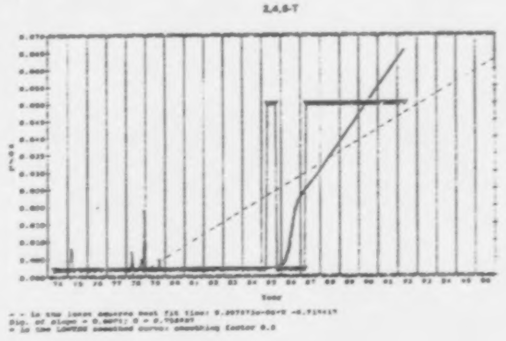
It would appear that the Seasonal Kendall Tau, Modified Seasonal Kendall Tau and the Van Belle trend statistics were influenced by the change in method and in detection limit. It is likely that the negative trend predicted by the non-parametric statistics is false and that in fact there is no significant change in total lead concentrations in the Assiniboine River, from the period 1980 to 1993.

Total lead concentrations in the river range from <0.0007 mg/L to 0.007 mg/L with a median concentration of 0.0012 mg/L. With no trend identified in lead concentrations and with no samples in many years exceeding the PPWB Water Quality Objective set at 0.02 mg/L, it is anticipated that lead will not be an issue in the Assiniboine River in the near future.

2,4,5-T

Trend analysis statistics for 2,4,5-T in the Assiniboine River are shown in Appendix 2. The Seasonal Kendall Tau, the Modified Seasonal Kendall Tau, and the Van Belle trends statistics for the entire data covering the period 1974 to 1992 indicate that concentrations of 2,4,5-T have increased, at the 5% significance level, in the Assiniboine River at the interprovincial boundary.

FIGURE 19

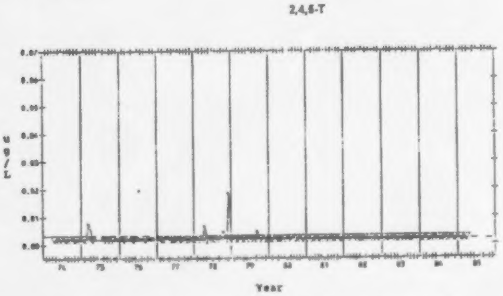


A series of trend statistics including the Mann and Kendall Tau and the Spearman Rank Correlations Coefficient were computed for each month (Appendix 2). Ten of the twelve months showed a significant positive trend in 2,4,5-T concentrations.

The time series graph in Figure 19 shows little variability in 2,4,5-T concentrations over the period 1974 to 1996. The least squares best fit line and the Significance of Slope statistic (0.0001) suggest a significant positive trend in 2,4,5-T concentrations. The Lowess smoothed curve with a factor of 0.5 suggests that 2,4,5-T concentrations increased in the Assiniboine River from the period 1985 to 1992.

In April 1985, however, the 2,4,5-T analytical method changed and the analytical detection limit increased from <0.01 μg/L to <0.05 μg/L. A time series graph representing the longest sample record with one method (1974 to 1985) was produced (Figure 20.) The least squares best fit line and the Significance of Slope statistic (0.1078) indicates there is no significant change in 2,4,5-T concentrations from 1974 to 1985. It would appear that the change in method and in detection limit was the cause of false positive non-parametric trend result for 2,4,5-T in the Assiniboine River.

FIGURE 20



- - is the least squares best fit line: -3.206607e-07*X +0.234249
Sig. of slope = 0.107814; R = 0.150744
= is the LOWESS smoothed curve; smoothing factor 0.5

The 2,4,5-T concentrations in the Assiniboine River at the Saskatchewan-Manitoba boundary range from <.001 μg/L to <.05 μg/L. With no significant trend in 2,4,5-T concentrations, no agricultural use, and a PPWB Water Quality Objective of 10.0 μg/L, which has never been exceeded, it is likely that 2,4,5-T concentrations in the Assiniboine River will not be a concern in the near future.

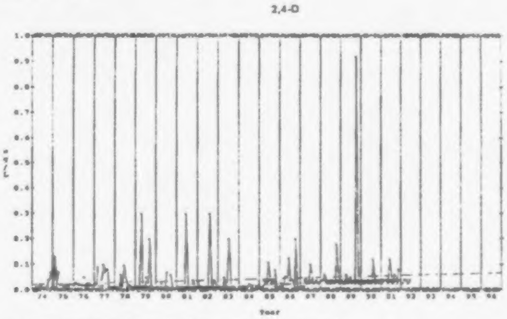
2,4-D

Detailed long-term trend analysis statistics for 2,4-D in the Assiniboine River are shown in Appendix 2. The Seasonal Kendall Tau, the Modified Seasonal Kendall Tau, and the Van Belle trends statistics for the overall results covering the period 1974 to 1992 indicate that concentrations of 2,4-D have increased, at the 5% significance level, in the Assiniboine River at the interprovincial boundary.

A series of trend statistics including the Mann and Kendall Tau and the Spearman Rank Correlations Coefficient were computed for each month (Appendix 2). The months of January and November showed a significant positive trend in 2,4-D concentrations.

The time series graph in Figure 21 shows the variability of 2,4-D concentrations over time. Elevated 2,4-D levels can occur at any particular time of year. Peaks in 2,4-D concentrations do not appear to be related to flow but perhaps to precipitation events. The least squares best fit line and the Significance of Slope statistic (0.1023) does not suggest a significant positive trend in 2,4-D concentrations. The Lowess smoothed curve with a factor of 0.5 suggests that 2,4-D concentrations increased slightly in the Assiniboine River from the period 1974 to 1992.

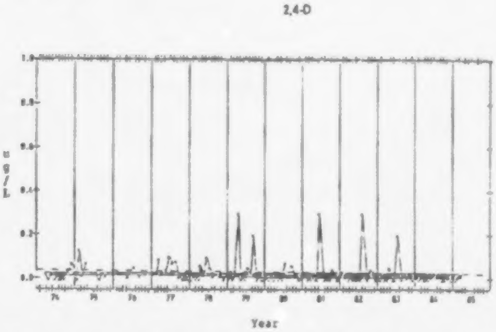
FIGURE 21



- - is the least squares best fit line: 5.120834e-06*X -3.814414
Sig. of slope = 0.102307; R = 0.110576
= is the LOWESS smoothed curve; smoothing factor 0.5

In April 1985 the 2,4-D analytical method changed and the analytical detection limit increased from <0.01 μg/L to <0.03 μg/L. A time series graph representing the period 1974 to 1985 (Figure 22) was produced which includes data from the earlier analytical method. The least squares best fit line and the Significance of Slope statistic (0.4466) shows there is no significant change in 2,4-D concentrations from 1974 to 1985. A time series graph (Figure 23) was also prepared for the period 1985 to 1992 and the Significance of Slope was 0.5334. It would appear that the change in analytical method and in detection limit caused a false positive non-parametric trend result for 2,4-D in the Assiniboine River.

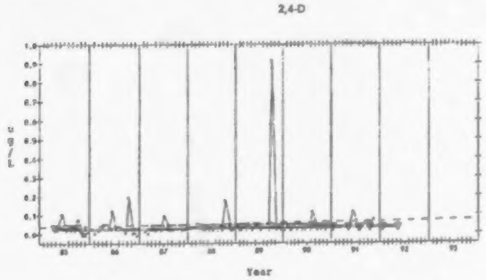
FIGURE 22



- - is the least squares best fit line: -3.536965e-06*X +2.585514
Sig. of slope = 0.446611; R = 0.071662
= is the LOWESS smoothed curve; smoothing factor 0.5

The 2,4-D concentrations in the Assiniboine River at the Saskatchewan-Manitoba boundary range from <.002 μg/L to .92 μg/L. With no significant trend in 2,4-D concentrations and a PPWB Water Quality Objective of 4.0 μg/L, 2,4-D concentrations in the Assiniboine River are not anticipated to be a concern in the near future.

FIGURE 23



- - is the least squares best fit line: 1.072604e-05*X -7.733529
Sig. of slope = 0.53349; R = 0.072535
= is the LOWESS smoothed curve; smoothing factor 0.5

SUMMARY AND RECOMMENDATIONS

Non-parametric statistical analysis and time series graphs, least squares best fit lines and Lowess smooth curves performed well in identifying monotonic long-term trends at PPWB monitoring locations. The non-parametric test results, in most cases, matched the plotted data, least squares best fit line and the Significance of Slope statistics. In situations where the results were not consistent, the Lowess smooth curve with a factor of 0.5 usually indicated a fluctuating trend over the 17 to 20-year period, or there was a significant method change with change in detection limit that influenced the non-parametric trend test results.

The time series plots were a useful tool in visually showing trends in water quality variables and in identifying changes in method and detection limits that could potentially influence the non-parametric trend results.

Long-term trends in a number of water quality variables collected from the PPWB monitoring sites were determined using non-parametric trend tests. The results indicate that there was no increasing trends for any water quality variable in the Assiniboine River near Kamsack.

Variables that showed a significant decrease in concentration over time included nickel total, Alpha-BHC and fecal coliforms.

Concentrations of boron, iron, copper, mercury and lead in the river appeared to be decreasing over the long-term, however, it appeared that the non-parametric trend analysis tests were influenced by a change in the analytical method or detection limit rather than a change in water quality.

The herbicides 2,4,5-T and 2,4-D appeared to be increasing according to non-parametric trend test results but the change was likely a direct result of a switch in analytical methods (detection limit).

A review of the trend results and a study of historical excursions to the PPWB objectives revealed that dissolved oxygen, total phosphorus and manganese displayed no long-term trends. However, because of elevated levels, they may become water quality concerns in the future. These constituents have the potential to affect fish, aquatic in stream weed growth and municipal water uses in the basin.

1) Monitoring for dissolved oxygen, total phosphorus and dissolved manganese should continue at a frequency that is capable of detecting long-term trends in water quality. This is recommended since levels of these variables already exceed the PPWB Water Quality Objective for the Assiniboine River and could potentially have a detrimental effect on down stream users in the basin.

2) A review of methods for improving the effluent quality from the town of Kamsack. This was also recommended by the 1991 Saskatchewan Environment study. A reduction of total phosphorus in the sewage effluent would reduce the potential for accelerated aquatic weed growth in the Assiniboine River.

ACKNOWLEDGEMENTS

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APPENDIX 1
DETAILED WATER QUALITY DATA BY VARIABLE
ASSINIBOINE RIVER NEAR KAMSACK

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Total Dissolved Solids ' Parameter Code '00201L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	788.	885.	360.	334.	449.	480.	651.	564	574.	656.	549.	834.
1982	1116.	-99.9900	909.	282.	381.	531.	497.	625.	613.	806.	856.	809.
1983	808.	-99.9900	738.	224.	501.	545.	549.	562.	542.	567.	567.	653.
1984	586.	592.	647.	349.	540.	526.	515.	584.	605.	1181.	-99.9900	695.
1985	847.	882.	388.	-99.9900	444.	539.	698.	720.	655.	1131.	727	713.
1986	1031.	844.	846.	251.	543.	651.	640.	646.	676.	1292.	717.	813.
1987	717.	683.	-99.9900	348.	446.	555.	516.	553.	591.	950.	738.	667.
1988	906.	868.	729.	307.	-99.9900	629.	530.	571.	593.	634.	688.	832.
1989	811.	868.	894.	529.	500.	522.	481.	-99.9900	484.	458.	555.	685.
1990	762.	819.	787.	200.	529.	534.	529.	510.	198.	542.	1439.	805.
1991	1121.	898.	783.	463.	415.	624.	524.	512.	547.	531.	787.	727.
1992	800.	731.	671.	243.	540.	625.	710.	684.	710.	1140.	596.	645.
1993	758.	813.	742.	366.	452.	539.	454.	518.	414.	510.	609.	772.
1994	756.	787.	762.	361.	501.	674.	606.	583.	642.	933.	754.	789.
1995	-99.9900		795. 753.	759.	573.	408.	602.	434.	396.	548.	577.	704.
1996	730.	738.	786.	318.	500.	585.	545.	-99.9900	677.	702.	767.	743.
1997	730.	761.	748.	-99.9900	-99.9900	-99.9900	559.	573.	635.	642.	796.	829.

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Field Conductivity ' Parameter '02041F '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	1246.	1400.	616.	567.	735.	819.	1123.	949.	1288.	1052.	975.	1268.
1982	1736.	1650.	1256.	490.	616.	740.	774.	835.	917.	1206.	1174.	-99.9900
1983	1158.	-99.9900	1128.	416.	788.	857.	860.	883.	846.	833.	869.	935.
1984	1090.	1090.	1130.	548.	876.	820.	830.	910.	916.	1805.	1010.	1020.
1985	1240.	1260.	570.	446.	734.	1390.	1030.	1080.	996.	1586.	1130.	1080.
1986	1214.	1296.	1320.	413.	915.	1006.	985.	1035.	1049.	1911.	1135.	1224.
1987	1147.	1092.	1076.	554.	738.	912.	814.	863.	900.	1468.	1220.	1104.
1988	1519.	1310.	1160.	539.	775.	963.	621.	885.	938.	927.	1056.	1161.
1989	1175.	1270.	1210.	782.	826.	817.	748.	-99.9900	774.	781.	855.	1037.
1990	1090.	1180.	1178.	330.	826.	832.	785.	808.	337.	845.	2141.	1181.
1991	1548.	1236.	1206.	761.	699.	981.	837.	762.	836.	853.	1200.	1082.
1992	1264.	1102.	1056.	392.	786.	946.	1165.	1062.	1086.	1755.	980.	1015.
1993	1185.	1241.	1118.	491.	738.	838.	730.	843.	632.	752.	843.	1184.
1994	1262.	1083.	1109.	589.	789.	998.	910.	932.	991.	1460.	1200.	1308.
1995	-99.9900	1290.	1165.	874.	613.	907.	628.	596.	822.	899.	1101.	1157.
1996	1144.	1149.	1162.	505.	774.	910.	882.	-99.9900	1041.	1093.	1187.	1148.
1997	1107.	1155.	1154.	-99.9900	-99.9900	-99.9900	869.	860.	922.	942.	1202.	1271.

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SAO5MD0002 '

'Turbidity .(Field) ' Parameter code '02073F '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	0.50	3.80	10.0	8.00	6.00	22.0	6.20	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1982	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	8.20	1.80	-99.9900	5.90
1983	6.70	-99.9900	5.80	124.	29.0	20.0	18.0	20.0	16.0	6.40	6.20	8.40
1984	4.70	7.40	4.40	35.0	12.0	33.0	17.0	10.0	10.2	14.0	7.40	8.80
1985	9.00	1.00	3.00	42.0	37.0	34.0	19.0	2.10	4.60	4.00	5.00	8.00
1986	7.20	7.00	6.80	22.0	34.0	38.0	26.5	18.7	11.5	15.5	-99.9900	6.50
1987	7.60	8.20	8.90	27.5	35.0	43.5	17.0	10.0	7.00	2.20	5.50	6.00
1988	20.5	14.5	15.5	27.0	24.5	30.5	16.0	9.00	5.50	5.00	4.00	4.00
1989	3.00	1.50	2.00	11.0	12.5	26.0	22.0	-99.9900	7.50	5.50	5.00	5.50
1990	6.20	4.25	3.50	44.0	7.20	9.00	6.00	4.00	3.00	3.00	3.00	5.50
1991	5.00	5.70	4.50	24.9	13.5	15.5	10.1	8.50	6.50	-99.9900	5.00	4.50
1992	3.50	4.00	7.00	64.0	15.0	11.1	11.0	7.00	4.70	7.00	4.50	6.00
1993	4.00	3.50	5.40	-99.9900	11.5	12.5	18.0	17.0	10.5	14.0	19.60	11.3
1994	3.80	10.0	13.0	17.3	15.0	18.8	23.3	13.8	10.1	4.40	5.60	10.7
1995	-99.9900	6.40	8.50	11.2	17.0	25.7	16.0	17.0	13.0	10.0	14.0	12.0
1996	9.20	11.0	8.30	27.3	13.2	28.0	25.0	-99.9900	20.2	12.3	17.6	14.1
1997	6.18	13.2	11.5	-99.9900	-99.9900	-99.9900	16.7	39.0	7.90	8.80	9.00	10.0

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Boron Dissolved ' Parameter Code '05105D '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	0.2600	0.1400	0.1900	0.1900	0.1900	0.1900	0.1700	0.1300	0.1400	0.1600	0.1100	0.1400
1982	0.1900	0.1800	0.1500	0.1800	0.1300	0.1400	0.1500	0.2000	0.1800	0.2600	0.1700	0.1900
1983	0.1600	-99.9900	0.1700	0.1900	0.1500	0.1700	0.1700	0.1800	0.1600	0.1800	0.1500	0.1600
1984	0.2600	0.2400	0.2200	0.2900	0.1500	0.1500	0.1500	0.1500	0.1500	0.1900	0.1600	0.1500
1985	0.2200	0.1800	0.1800	0.1400	0.1500	0.1600	0.1600	0.1400	0.1400	0.1900	0.1600	0.1100
1986	0.1100	0.1100	0.1200	0.1100	0.1400	0.1300	0.1600	0.1500	0.1800	0.2200	0.1300	0.1700
1987	0.1500	0.1400	0.1600	0.1300	0.1200	0.1400	0.1500	0.1400	0.1500	0.1800	0.1400	0.1300
1988	0.1600	0.1900	0.1700	0.1210	0.1570	0.1480	0.1500	0.1580	0.1740	0.1810	0.1560	0.1760
1989	0.1650	0.1920	0.2060	0.2310	0.2500	0.2360	0.2460	-99.9900	0.2130	0.2300	0.2430	0.1840
1990	0.1330	0.1510	0.1530	0.1780	0.2200	0.0700	0.0830	0.0840	0.0980	0.0960	0.1120	-99.9900
1991	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1992	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1993	0.0330	0.0670	0.0620	0.0380	0.0550	0.0680	0.0500	0.0600	0.0440	0.0350	0.0580	0.0560
1994	0.0530	0.0600	0.0630	0.0330	0.0570	0.0740	0.0690	0.0710	0.0610	0.0870	0.0790	0.0550
1995	-99.9900	0.0510	0.0670	0.0480	0.0310	0.0730	0.0580	0.0470	0.0590	0.0670	0.0660	0.0470
1996	0.0510	0.0720	0.0700	0.0380	0.0500	0.0730	0.0660	-99.9900	0.0830	0.0930	0.0830	0.0750
1997	0.0700	0.0760	0.0770	-99.9900	-99.9900	-99.9900	0.0790	0.0820	0.0800	0.0890	0.1030	0.0840

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Nitrate & Nitrite ' Parameter '07106L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	0.1000	0.1600	0.4500	-99.9900	-99.9900	0.0700	-99.9900	-99.9900	-99.9900	-99.9900	0.0100	0.0100
1982	0.0500	0.0500	0.1000	0.0600	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0700	0.0400	0.0400
1983	0.1400	-99.9900	0.4600	1.7000	-99.9900	-99.9900	0.1900	-99.9900	0.0500	-99.9900	0.0100	0.0200
1984	0.1600	0.2700	0.5200	2.00	-99.9900	0.0400	-99.9900	-99.9900	-99.9900	0.0500	0.1000	0.2600
1985	0.7500	1.00	0.7000	0.6000	0.0400	0.0700	0.0500	-99.9900	0.0200	0.2100	0.0200	0.0500
1986	0.2300	0.3700	0.5300	0.3100	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0100	0.0500
1987	0.2100	0.3800	0.4600	0.0700	-99.9900	0.0100	0.0900	-99.9900	-99.9900	0.0600	-99.9900	0.0100
1988	0.0800	0.1800	0.6000	-99.9900	0.0160	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0350	0.0460
1989	0.1340	0.2100	0.3740	0.5520	0.0180	0.0430	0.0570	-99.9900	-99.9900	-99.9900	0.0100	0.0540
1990	0.0940	0.2920	0.3560	0.5320	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0220	0.0180
1991	0.0510	0.0900	0.2680	0.8250	-99.9900	-99.9900	-99.9900	-99.9900	0.0140	-99.9900	0.0260	0.0400
1992	0.1230	0.2530	0.3300	0.9850	-99.9900	-99.9900	-99.9900	-99.9900	0.0160	0.0950	-99.9900	0.0270
1993	0.0970	0.2160	0.2640	0.0780	-99.9900	-99.9900	0.0450	0.0110	0.0470	-99.9900	-99.9900	0.2690
1994	0.3190	0.4560	0.8200	1.1870	-99.9900	0.0860	0.0420	0.0050	-99.9900	0.0690	-99.9900	0.0250
1995	-99.9900	0.5560	1.5600	1.0400	-99.9900	-99.9900	0.0410	-99.9900	0.0100	-99.9900	0.1250	0.1870
1996	0.5690	0.7530	0.9890	0.8840	-99.9900	0.0140	0.0170	-99.9900	0.0480	-99.9900	0.0650	0.1490
1997	0.2960	0.3310	0.3580	-99.9900	-99.9900	-99.9900	-99.9900	0.0400	-99.9900	-99.9900	0.0310	0.0290

-99.9900 indicates missing data & less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Ammonia total ' Parameter '07503L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.2000	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1982	-99.9900	0.7000	1.0000	0.1000	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	2.000	-99.9900	0.2000
1983	0.4000	-99.9900	0.2000	0.4000	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1984	0.2000	0.2000	0.1000	0.3000	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.5400	0.1600	0.3000
1985	0.3900	0.2100	0.1800	-99.9900	0.1100	-99.9900	0.1200	0.1400	-99.9900	0.8000	-99.9900	0.1400
1986	0.3600	0.3200	0.1200	-99.9900	0.0600	-99.9900	-99.9900	-99.9900	0.0800	-99.9900	0.0900	0.2000
1987	0.1200	0.2300	0.2100	0.1800	-99.9900	0.0500	0.1400	0.0260	0.0250	0.5300	0.0220	0.0410
1988	0.0730	0.3620	0.2080	0.0270	0.1490	0.0270	0.0380	0.0280	0.0250	0.0220	0.1110	0.1510
1989	0.2850	0.3090	0.2520	0.2230	2.5200	0.1140	0.1040	-99.9900	0.0230	0.0220	0.0500	0.1770
1990	0.2640	0.2620	0.2150	0.2000	0.0320	0.0320	0.0330	0.0300	0.0370	0.0790	0.0650	0.1420
1991	0.3410	0.3490	0.2640	0.4400	0.0170	0.0570	0.0220	0.0100	0.0870	0.1120	0.2230	0.1900
1992	0.2580	0.1730	0.1230	0.2890	0.0260	0.0300	0.0500	0.0480	0.0800	0.9200	0.0350	0.0930
1993	0.2440	0.2210	0.1710	0.0320	0.0740	0.0300	0.1080	0.0470	0.0260	0.0300	0.0280	0.2770
1994	0.5750	0.5850	0.2580	0.1600	0.0380	0.0340	0.0920	0.0410	0.0280	0.0780	0.0290	0.0630
1995	-99.9900	0.2610	0.3100	0.8500	0.0140	-99.9900	0.0290	0.0260	0.0260	0.0270	0.1390	0.3320
1996	0.3980	0.4700	0.2830	0.1930	0.0370	0.0520	0.0380	-99.9900	0.0350	0.0460	0.0610	0.1430
1997	0.2500	0.2660	0.1380	-99.9900	-99.9900	-99.9900	0.0410	0.0350	0.0280	0.0220	0.0380	0.0330

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Total Nitrogen ' Parameter '07602L '

Year	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
1981	0.9900	1.0600	1.4200	1.0300	0.8500	0.9700	0.8600	0.9300	0.8000	0.9100	0.8100	0.8400
1982	1.1700	1.1800	1.0800	1.1100	0.7400	0.8100	0.9800	0.9500	0.7400	2.1900	0.6200	0.6100
1983	0.7000	-99.9900	0.9600	2.9700	1.0400	0.9300	-99.9900	0.9200	0.8100	0.6200	0.5500	0.5400
1984	0.7700	0.8700	0.9500	2.9200	0.8000	1.1900	1.2800	0.8000	0.7700	1.1100	0.7400	0.7800
1985	1.2700	1.5800	1.5200	1.2800	0.8500	0.9300	0.7700	0.5400	0.6200	2.0600	0.5300	0.5900
1986	0.9000	1.0200	0.9300	1.0900	0.9700	1.3200	1.2800	0.9600	1.0000	1.6400	0.6600	0.5700
1987	0.9200	0.8400	1.1500	1.1200	1.0500	1.1000	0.8300	0.7700	0.7800	1.4300	0.7500	0.7500
1988	2.2600	2.4700	2.1900	1.0600	1.2300	1.2600	0.9860	0.7930	0.7350	0.6740	0.5930	0.6930
1989	0.8540	0.8780	0.9790	1.5000	3.7200	0.7610	0.7620	-99.9900	0.5420	0.6170	0.4500	0.7390
1990	0.7860	0.8970	0.9460	1.6100	0.7480	0.7000	0.6310	0.6930	0.5250	0.6310	0.8130	0.8260
1991	0.8230	0.5000	0.7190	2.2200	0.6250	0.6190	0.4220	0.4560	0.3760	0.3440	0.4740	0.4100
1992	0.4200	0.6380	0.6610	1.8500	0.5270	0.4310	0.4620	0.4260	0.4490	1.2300	0.3020	0.4410
1993	0.4270	0.5400	0.7280	1.0100	0.4430	0.4570	0.6740	0.5050	0.5960	1.2200	1.2900	1.6600
1994	1.7300	1.9400	1.8600	1.6400	1.1600	1.6500	1.7300	1.5100	1.1000	1.2900	0.9950	1.3200
1995	-99.9900	1.5900	2.8700	2.8200	1.1100	1.7600	1.4800	1.2300	1.2500	1.0000	1.8500	2.0200
1996	1.7900	2.0100	2.0100	2.2800	1.2700	1.4300	1.1100	-99.9900	1.2700	1.0400	1.9400	1.9200
1997	2.2000	2.1800	1.9700	-99.9900	-99.9900	-99.9900	1.0700	1.0600	0.8900	0.9100	1.0900	1.5600

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SA05MD0002 '

'pH(Field) ' Parameter code '10301F '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	7.40	7.50	8.20	7.80	7.90	7.90	8.40	8.30	8.40	8.40	8.30	8.00
1982	7.50	7.50	7.40	7.80	8.00	8.10	8.20	8.10	8.10	8.10	7.80	8.10
1983	7.60	-99.9900	7.60	7.60	8.10	8.10	8.00	8.20	8.10	8.10	8.30	7.80
1984	7.50	7.30	7.40	7.80	8.10	8.00	8.10	8.10	8.20	8.10	7.70	7.50
1985	7.40	7.80	8.30	8.10	7.70	7.90	7.70	8.10	8.10	8.10	8.00	7.90
1986	7.60	7.50	7.90	7.80	7.90	7.90	8.00	8.20	8.00	8.10	8.30	7.60
1987	7.00	7.60	7.90	8.20	8.10	8.00	7.70	8.10	8.20	8.20	8.20	7.80
1988	7.00	7.70	7.50	8.00	8.10	8.00	8.20	8.20	8.10	7.90	7.80	7.70
1989	7.40	7.50	7.20	7.40	7.80	7.80	7.90	-99.9900	8.10	8.00	8.10	7.75
1990	7.30	7.80	7.60	7.50	8.10	8.30	8.36	8.12	8.17	7.93	7.90	7.48
1991	7.44	7.56	7.86	7.75	8.02	8.09	7.94	7.97	8.22	8.01	7.61	7.45
1992	7.30	7.19	7.38	7.70	7.91	7.77	8.26	8.36	8.05	8.22	8.16	7.61
1993	7.48	7.07	7.20	8.48	8.42	7.34	7.41	7.75	7.22	7.30	8.19	7.55
1994	7.34	7.84	7.84	7.86	7.93	7.80	7.79	8.24	7.89	8.28	8.33	7.88
1995	-99.9900	7.65	7.40	7.90	7.00	7.97	7.40	7.60	8.16	8.09	8.00	7.80
1996	7.66	7.33	7.44	7.64	8.03	8.06	8.07	-99.9900	8.43	8.07	8.47	7.84
1997	8.02	7.90	7.81	-99.9900	-99.9900	-99.9900	8.05	8.07	8.39	8.78	8.00	7.79

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002
'Dissolved Oxygen ' Parameter '08101F '

year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	5.2	8.0	11.7	9.5	10.1	6.6	9.0	5.3	9.7	10.8	12.5	12.2
1982	2.2	2.2	4.1	9.9	8.4	7.8	7.6	7.7	8.7	10.5	8.9	7.9
1983	7.2	-99.9900	7.4	8.7	8.5	7.7	7.1	8.2	10.1	9.7	12.5	10.7
1984	5.5	5.3	6.3	10.8	10.5	7.7	8.4	7.7	9.6	7.8	7.9	7.9
1985	5.9	5.6	10.5	9.0	-99.9900	-99.9900	6.1	9.0	8.0	10.8	9.9	7.0
1986	6.0	5.6	7.3	11.2	8.0	7.7	7.5	6.8	8.8	11.5	10.5	6.9
1987	6.5	6.5	7.8	10.4	8.6	7.2	6.9	8.5	9.3	10.7	12.0	11.0
1988	7.5	6.3	7.5	11.1	9.0	7.9	10.0	8.1	8.5	9.8	9.0	7.8
1989	3.2	3.5	3.9	10.5	8.3	5.3	6.5	-99.9900	9.4	10.8	11.4	8.8
1990	5.2	4.8	5.2	10.8	10.8	8.4	13.0	8.2	7.5	9.6	11.6	6.7
1991	3.2	3.3	4.3	10.8	10.2	9.0	6.4	7.4	9.0	10.5	9.2	5.3
1992	3.9	4.7	6.8	11.2	9.6	6.9	7.2	8.0	8.55	6.8	12.5	7.9
1993	3.3	3.7	8.9	16.1	9.3	6.7	6.4	6.3	9.4	11.8	12.9	5.8
1994	5.1	4.3	5.7	12.5	8.4	8.1	6.8	7.9	6.8	9.2	11.3	9.8
1995	-99.9900	5.6	8.2	10.0	9.0	6.5	6.2	6.0	7.3	9.8	11.2	5.0
1996	7.86	6.4	9.23	7.74	6.02	6.25	4.56	-99.9900	6.15	6.5	8.17	7.05
1997	6.18	5.46	4.74	-99.9900	-99.9900	-99.9900	11.34	10.9	8.5	9.6	12.1	11.2

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Non-Filterable Residues ' Parameter '10401L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	6.00	12.0	16.0	19.0	9.00	38.0	11.0	13.0	8.00	9.00	7.00	9.00
1982	16.0	4.00	6.00	20.0	17.0	24.0	15.0	10.0	4.00	3.00	12.0	21.0
1983	11.0	- 99.9900	7.00	156.	36.0	21.0	15.0	17.0	9.00	5.00	-99.9900	7.00
1984	4.00	5.00	4.00	3.0	18.0	119.	25.0	12.0	11.0	16.0	3.00	10.0
1985	7.00	8.00	24.0	22.0	53.0	33.0	12.0	4.00	4.00	2.00	5.00	6.00
1986	6.00	6.00	5.00	32.0	53.0	40.0	28.0	17.0	10.0	17.0	4.00	5.00
1987	5.00	5.00	7.00	37.0	39.0	54.0	16.0	12.0	9.00	2.00	6.00	4.00
1988	26.0	24.0	22.0	39.0	32.0	35.0	11.5	7.20	4.40	3.00	2.00	2.00
1989	1.20	1.00	1.40	7.60	12.4	28.8	22.4	-99.9900	4.80	2.80	4.40	6.00
1990	3.60	3.20	3.40	74.0	10.4	7.4	7.00	6.00	-99.9900	2.40	1.20	3.20
1991	3.20	1.80	2.00	32.0	18.4	22.0	8.40	8.80	6.00	2.40	2.00	3.00
1992	2.60	2.20	4.00	69.2	18.0	15.2	14.0	7.00	3.80	5.60	3.60	5.20
1993	1.60	2.20	4.60	15.6	14.8	17.0	37.8	15.0	16.0	11.0	16.8	9.80
1994	7.60	7.80	10.40	24.2	23.2	30.0	36.8	15.6	10.2	3.20	4.00	10.9
1995	-99.9900	5.00	6.50	11.1	29.8	38.6	25.2	36.8	19.0	8.20	16.4	21.2
1996	7.80	6.60	5.40	45.6	33.80	33.8	33.2	-99.9900	22.4	16.6	21.6	18.0
1997	16.4	15.40	12.0	-99.9900	-99.9900	-99.9900	28.0	23.6	6.80	11.2	9.60	10.0

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Sodium Dissolved' Parameter '11103L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	51.0	47.0	24.0	18.0	23.0	39.5	69.0	56.0	50.0	68.0	38.0	60.0
1982	70.0	76.0	54.0	14.0	24.0	36.0	31.0	58.0	58.0	95.0	67.0	62.0
1983	50.0	-99.9900	50.0	12.0	33.0	38.0	43.0	38.0	36.0	38.0	36.1	44.5
1984	45.8	51.0	50.2	15.6	34.3	27.0	34.4	39.4	42.1	174.	53.5	46.6
1985	64.7	70.4	31.9	12.8	28.6	39.7	42.5	48.3	47.8	133.	49.0	43.1
1986	177.	62.1	67.8	10.6	31.9	36.7	37.0	47.2	49.8	183.	46.1	46.9
1987	44.0	38.6	-99.9900	18.1	25.7	37.7	33.5	36.4	35.3	117.9	70.6	45.4
1988	36.3	33.6	13.3	14.5	-99.9900	32.7	28.4	40.8	42.0	52.8	48.1	52.6
1989	49.2	50.9	54.0	26.7	52.0	40.0	31.5	-99.9900	39.9	37.4	36.0	51.0
1990	50.0	55.0	53.0	10.0	35.8	33.4	35.1	39.0	13.5	44.0	203.	78.2
1991	78.5	63.0	51.5	45.0	32.0	57.5	43.5	37.9	45.4	58.0	74.8	59.0
1992	64.8	51.0	53.6	13.1	38.3	46.0	80.5	73.6	94.0	172.	66.7	43.7
1993	64.4	62.4	69.0	31.4	33.7	43.3	33.9	33.0	18.1	27.1	38.0	56.7
1994	49.0	50.6	49.8	21.6	34.5	47.5	39.7	42.9	50.0	108.	73.4	68.8
1995	-99.9900	69.9	56.5	46.9	22.8	35.4	17.1	17.5	32.4	37.1	36.7	37.2
1996	39.5	42.9	47.3	16.3	28.2	35.7	32.1	-99.9900	48.6	51.1	41.9	36.3
1997	32.0	34.0	28.8	-99.9900	-99.9900	-99.9900	33.7	37.4	43.5	43.9	60.6	48.7

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Total Phosphorus' Parameter '15406L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	0.0440	0.0680	0.1300	0.0830	0.0710	0.1500	0.2000	0.2000	0.1500	0.1700	0.1700	0.1800
1982	0.1400	0.0750	0.0600	0.2600	0.1200	0.1700	0.1200	0.3900	0.1600	-99.9900	0.0810	0.0600
1983	0.0450	-99.9900	0.0680	0.3100	0.1300	0.1500	0.3500	0.2000	0.1100	0.0870	0.0590	0.0520
1984	0.0570	0.0610	0.0630	0.2400	0.1000	0.1400	0.2200	0.1800	0.1100	0.7300	0.0600	0.0600
1985	0.0720	0.0760	0.6000	0.1500	0.1700	0.1300	0.1300	0.0530	0.0660	0.8000	0.0550	0.0620
1986	0.0530	0.0530	0.0610	0.1500	0.1500	0.2100	0.2000	0.1100	0.0900	0.5500	0.0690	0.0590
1987	0.0790	0.0800	0.1000	0.1600	0.1300	0.1300	0.1200	0.1000	0.0980	0.4400	0.0600	0.0500
1988	0.0800	0.0670	0.1600	0.1300	0.1600	0.1890	0.1820	0.1370	0.1100	0.0750	0.0570	0.0550
1989	0.0430	0.0380	0.0490	0.1950	0.8100	0.1120	0.1340	-99.9900	0.1210	0.0940	0.0600	0.0580
1990	0.0460	0.0480	0.0410	0.2910	0.0980	0.0710	0.0760	0.1090	0.0990	0.0770	0.1040	0.0600
1991	0.0530	0.0400	0.0390	0.3140	0.1060	0.1350	0.1330	0.1360	0.1880	0.1170	0.1170	0.0760
1992	0.0530	0.0500	0.0580	0.2870	0.1740	0.1100	0.1210	0.2110	0.2910	1.1760	0.1160	0.0830
1993	0.0750	0.0790	0.1510	0.2200	0.1430	0.1470	0.1850	0.2020	0.1140	0.1210	0.1360	0.1150
1994	0.1050	0.1070	0.1330	0.2160	0.1870	0.2950	0.2400	0.2070	0.1680	0.3450	0.0970	0.1080
1995	-99.9900	0.0840	0.2370	0.3120	0.0920	0.2180	0.1470	0.1440	0.1130	0.0750	0.1020	0.1020
1996	0.0830	0.0810	0.0950	0.2000	0.1070	0.1450	0.1150	-99.9900	0.1010	0.0760	0.1060	0.1040
1997	0.1000	0.1270	0.0710	-99.9900	-99.9900	-99.9900	0.1000	0.0940	0.0810	0.0880	0.0680	0.0680

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SA05MD0002 '

'Sulphate Dissolved ' Parameter code '16304L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	200.	235.	89.0	89.0	121.	117.	167.	151.	159.	198.	136.	225.
1982	300.	300.	252.	82.0	96.0	146.	118.	192.	190.	264.	300.	266.
1983	220.	-99.9900	200.	76.0	184.	156.	163.	158.	148.	160.	191.	209.
1984	211.	215.	212.	137.	194.	182.	169.	164.	174.	440.	219.	225.
1985	249.	257.	94.4000	117.	153.	166.	266.	261.	232.	457.	249.	213.
1986	420.	238.	236.	80.3	179.	246.	226.	225.	222.	522.	215.	262.
1987	179.	168.	-99.9900	117.	138.5	175.	148.	159.	175.	340.	253.	165.
1988	424.	401.	296.	104.	-99.9900	234.	133.	161.	184.	215.	231.	300.
1989	236.	245.	255.	187.	156.	156.	132.	-99.9900	132.	120.	204.	220.
1990	219.	208.	215.	56.0	164.	150.	150.	155.	41.3	176.	609.	255.
1991	444.	276.	250.	161.	145.	190.	132.	122.	123.	118.	247.	236.
1992	242.	200.	168.	74.0	189.	190.	224.	202.	227.	415.	166.	210.
1993	198.	224.	199.	90.8	99.6	138.	131.	126.	78.8	117.	150.	195.
1994	191.	201.	194.	105.	132.	225.	207.	149.	195.	383.	231.	205.
1995	-99.9900	195.	229.	177.	149.	212.	111.	117.	167.	175.	291.	319.
1996	221.	202.	217.	115.	183.	190.	139.	-99.9900	229.	234.	314.	323.
1997	305.	315.	315.	-99.9900	-99.9900	-99.9900	169.	168.	181.	183.	283.	304.

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SA05MD0002 '

'Chloride Dissolved ' Parameter '17206L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	19.0	21.0	19.0	6.00	9.5	28.0	87.0	35.0	25.0	42.0	21.0	54.0
1982	52.0	42.0	26.0	10.0	12.0	20.0	12.0	46.0	29.0	67.0	28.0	22.0
1983	20.0	-99.9900	23.0	6.60	15.0	18.0	13.0	14.0	11.0	11.0	9.40	14.3
1984	19.1	25.0	23.7	7.90	18.0	9.80	13.3	12.6	14.6	121.	-99.9900	17.5
1985	49.0	40.7	36.9	4.10	14.4	17.1	22.2	21.6	21.6	91.7	25.9	18.3
1986	90.0	39.8	49.9	5.00	15.4	19.2	17.7	29.4	24.1	133.3	15.4	16.9
1987	15.7	16.9	-99.9900	8.80	13.2	19.1	12.6	15.0	10.8	83.7	48.0	21.9
1988	14.0	11.0	14.7	6.00	-99.9900	17.6	7.90	10.4	13.1	20.1	17.5	17.9
1989	15.6	16.5	23.5	12.6	39.3	24.9	15.4	-99.9900	13.5	12.0	12.7	30.6
1990	23.4	30.5	25.6	6.00	22.5	17.4	13.6	15.4	4.80	14.5	146.	47.5
1991	37.9	28.0	20.6	36.6	19.2	53.7	25.1	21.1	26.2	28.3	50.9	28.4
1992	42.4	27.9	44.3	7.17	22.2	26.9	66.	57.2	76.8	150.	57.6	30.7
1993	39.5	36.2	72.2	26.1	20.4	28.1	23.7	16.9	6.30	19.6	24.6	32.9
1994	31.3	28.0	31.0	13.5	16.9	22.4	14.8	18.0	21.7	72.9	46.2	51.0
1995	-99.9900	47.6	35.8	31.7	9.9	17.5	6.70	6.71	11.4	14.5	16.9	16.3
1996	14.7	20.0	23.2	7.04	11.8	16.3	12.2	-99.9900	20.5	19.5	20.5	19.5
1997	15.1	17.1	10.7	-99.9900	-99.9900	-99.9900	12.5	11.8	13.6	13.4	22.5	28.7

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SA05MD0002 '

'a-BHC ' Parameter Code '18075L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1975	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0080	0.0050	0.0050	-99.9900	-99.9900
1976	-99.9900	0.0040	-99.9900	-99.9900	0.0060	-99.9900	0.0050	-99.9900	0.0040	-99.9900	-99.9900	-99.9900
1977	-99.9900	0.0020	-99.9900	-99.9900	0.0050	-99.9900	0.0020	-99.9900	0.0030	-99.9900	-99.9900	-99.9900
1978	-99.9900	0.0020	-99.9900	-99.9900	0.0070	0.0050	0.0040	0.0130	0.0100	0.0050	0.0050	0.0040
1979	0.0040	0.0030	0.0010	0.0050	0.0070	0.0040	-99.9900	0.0030	0.0200	0.0100	0.0040	0.0070
1980	0.0060	0.0030	0.0010	0.0040	0.0080	0.0050	0.0080	0.0090	0.0090	0.0100	0.0030	0.0080
1981	0.0010	0.0020	0.0040	0.0020	0.0030	0.0070	0.0100	0.0060	0.0100	0.0100	0.0050	0.0080
1982	0.0060	0.0030	0.0040	0.0030	0.0030	0.0020	0.0030	0.0050	0.0070	0.0080	0.0080	0.0040
1983	-99.9900	-99.9900	-99.9900	0.0030	0.0010	-99.9900	-99.9900	0.0010	0.0050	0.0090	0.0100	0.0090
1984	0.0030	0.0040	0.0020	0.0040	0.0030	0.0050	0.0040	0.0040	0.0040	0.0030	0.0030	0.0020
1985	0.0020	-99.9900	0.0020	0.0050	0.0030	0.0060	0.0020	0.0030	0.0020	0.0030	0.0020	0.0030
1986	0.0020	0.0010	0.0020	0.0040	0.0040	0.0040	0.0030	-99.9900	-99.9900	0.0030	0.0020	-99.9900
1987	-99.9900	-99.9900	0.0020	0.0030	0.0030	0.0010	0.0030	0.0020	0.0010	0.0020	0.0020	-99.9900
1988	0.0010	0.0030	0.0020	0.0020	-99.9900	0.0020	-99.9900	-99.9900	-99.9900	0.0020	0.0020	0.0020
1989	0.0010	-99.9900	0.0040	0.0020	-99.9900	0.0040	0.0020	-99.9900	-99.9900	0.0020	0.0020	-99.9900
1990	0.0010	-99.9900	-99.9900	0.0010	0.0020	0.0020	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK '   STATION NUMBER   'OOSAO5MD0002'

'Calcium Dissolved '   Parameter '20101L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	98.	119.	60.6	66.5	86.0	76.9	82.4	78.8	81.4	82.0	88.9	125.
1982	169.	155.	163.	45.0	67.1	87.5	86.5	89.3	87.8	97.0	129.	109.
1983	145.	-99.9900	120.	36.7	78.1	88.9	81.0	87.5	85.9	93.8	107.	116.
1984	59.1	59.0	79.8	55.5	86.3	88.7	66.7	97.7	94.2	102.	102.	103.4
1985	128.	140.	54.4	46.4	68.7	84.5	91.7	99.2	91.9	122.	106.	114.
1986	78.1	131.	128.	41.5	76.4	78.6	82.8	77.6	85.8	113.	110.	132.
1987	120.2	118.	-99.9900	57.0	73.1	85.9	85.2	90.5	97.5	105.8	98.3	113.
1988	69.0	70.1	89.9	51.9	-99.9900	77.0	89.1	87.6	85.4	93.6	110.	131.
1989	139.	152.	156.	86.0	71.2	81.0	79.5	-99.9900	72.0	69.0	84.0	100.
1990	118.	139.	128.	32.6	81.0	91.5	86.4	71.5	37.7	73.0	131.	101.
1991	169.	146.	120.	56.0	59.0	80.0	78.0	81.6	86.0	75.7	100.	103.
1992	120.	129.	105.	39.9	79.0	94.5	76.5	83.0	74.0	94.5	69.0	93.0
1993	120.	138.	101.	53.8	80.5	81.8	68.7	84.8	82.1	93.9	107.	127.
1994	133.	136.	130.	55.0	79.7	105.	87.9	92.0	95.1	108.	103.	120.
1995	-99.9900	121.	120.	81.2	61.7	78.6	76.7	68.4	87.7	92.3	77.5	81.0
1996	119.	128.	128.	47.7	77.5	92.8	95.6	-99.9900	101.	106.	84.9	76.2
1997	74.4	78.3	77.8	-99.9900	-99.9900	-99.9900	91.3	92.7	107.	108.	114.	102.

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SA05MD0002 '

'Manganese Dissolved ' Parameter Code '25104D '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1979	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0500	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1980	-99.9900	-99.9900	-99.9900	0.0600	0.0400	0.0300	0.0500	0.1600	0.2100	0.2000	0.0900	0.1200
1981	0.2800	0.9000	0.0800	0.0300	0.1900	0.5100	0.1100	-99.9900	0.0300	0.0500	0.0200	0.0500
1982	1.1000	3.1000	1.8000	0.0500	0.0800	0.1700	0.0100	0.0400	0.0100	0.1700	0.0600	0.1000
1983	0.2400	-99.9900	0.2000	0.1200	0.1000	0.1500	0.1900	0.1300	0.3600	0.2400	0.1000	0.1000
1984	0.3000	0.4000	0.3700	0.0900	0.0500	0.1600	0.1000	0.4300	0.5000	0.6100	0.1000	0.1100
1985	0.2300	0.2100	0.0500	0.0200	0.1000	0.0900	0.1100	0.1800	0.3700	0.2500	0.1200	0.1800
1986	0.0300	0.3100	0.2190	0.0310	0.0210	0.0670	0.0560	0.1650	-99.9900	0.1110	0.1920	0.2320
1987	0.3320	0.2660	0.2110	0.0380	0.0100	0.1440	0.2000	0.1730	0.0700	0.1550	0.0610	0.0750
1988	0.0220	0.0720	0.1760	0.0450	0.0490	0.0300	0.0600	0.0300	0.1750	0.1420	0.1870	0.2780
1989	0.4690	0.5100	0.3770	0.3600	0.1360	0.4370	0.2380	-99.9900	0.0290	0.0150	0.0440	0.1350
1990	0.2740	0.2050	0.1870	0.0760	0.0130	0.1040	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1991	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1992	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.1890	0.0090	0.0040	0.1090	0.1620	0.0300	0.0990
1993	0.3500	0.3960	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SA05MD0002 '

'Iron Dissolved ' Parameter Code '26104D '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1979	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0400	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1980	-99.9900	-99.9900	-99.9900	0.0600	-99.9900	-99.9900	-99.9900	-99.9900	0.0500	-99.9900	-99.9900	0.0400
1981	0.0400	-99.9900	0.0600	0.0400	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0900	0.1400
1982	0.0700	0.0400	0.0400	0.1800	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0400	-99.9900
1983	-99.9900	-99.9900	-99.9900	0.0900	0.0500	0.0400	0.5900	0.1000	-99.9900	-99.9900	-99.9900	0.0600
1984	0.0600	0.0800	-99.9900	0.1000	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0500	0.0700
1985	0.0400	0.0500	0.0600	0.0700	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0500	0.0400	-99.9900
1986	-99.9900	-99.9900	0.0470	0.1040	0.0280	0.0210	-99.9900	0.0200	0.0310	0.0540	0.0190	0.0330
1987	0.0350	0.0340	0.0360	0.0740	0.0390	0.0210	0.0170	0.0180	0.0100	0.0260	0.0280	0.0340
1988	0.0240	0.0280	0.1620	0.0830	0.0580	0.0420	0.0220	0.0190	0.0140	0.0220	0.0140	0.0120
1989	0.0400	0.0330	0.0480	0.0940	0.0380	0.0190	0.0180	-99.9900	0.0100	0.0330	0.0250	0.0610
1990	0.0610	0.0280	0.0250	0.0960	0.0290	0.0190	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1991	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1992	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0330	0.0120	0.2200	0.0190	0.0690	0.0270	0.0330
1993	0.0610	0.0500	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Total Copper' Parameter Code '29005P '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	0.0070	0.0030	0.0030	0.0040	0.0040	0.0020	0.0030	0.0020	0.0020	0.0040	-99.9900	0.0020
1982	0.0010	0.0020	0.0010	0.0080	0.0050	0.0030	0.0020	0.0020	0.0020	0.0020	0.0020	0.0010
1983	0.0010	-99.9900	0.0020	0.0060	0.0030	0.0020	0.0010	0.0040	0.0030	0.0020	0.0010	0.0020
1984	0.0070	0.0020	-99.9900	0.0100	0.0060	0.0030	0.0020	0.0020	0.0020	0.0030	0.0060	0.0010
1985	0.0110	0.0330	0.0060	0.0030	0.0030	0.0030	0.0020	0.0020	0.0020	0.0010	0.0010	0.0020
1986	0.0020	0.0020	0.0030	0.0030	0.0030	0.0030	0.0020	0.0191	0.0015	0.0020	0.0020	0.0034
1987	0.0020	0.0047	0.0095	0.0093	0.0111	0.0025	0.0017	0.0118	0.0022	0.0027	0.0038	0.0032
1988	0.0017	0.0025	0.0038	0.0038	0.0027	0.0018	0.0015	0.0019	0.0016	0.0012	0.0012	0.0013
1989	0.0007	0.0009	0.0010	0.0012	0.0040	0.0015	0.0017	-99.9900	0.0011	0.0010	0.0012	0.0017
1990	0.0013	0.0010	0.0020	0.0038	0.0014	0.0013	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1991	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1992	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0014	0.0008	0.0014	0.0011	0.0042	0.0010	0.0024
1993	0.0012	0.0014	0.0022	0.0014	0.0013	0.0024	0.0017	0.0017	0.0012	0.0010	0.0013	0.0025
1994	0.0029	0.0021	0.0022	0.0020	0.0028	0.0023	0.0016	0.0021	0.0013	0.0020	0.0018	0.0015
1995	-99.9900	0.0014	0.0014	0.0021	0.0019	0.0029	0.0020	0.0021	0.0016	0.0013	0.0025	0.0020
1996	0.0012	0.0125	0.0017	0.0024	0.0021	0.0026	0.0031	-99.9900	0.0027	0.0026	0.0019	0.0012
1997	0.0011	0.0013	0.0011	-99.9900	-99.9900	-99.9900	0.0020	0.0050	0.0100	0.0110	0.0060	0.0010

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Zinc Total ' Parameter '30005P '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	0.0060	0.0520	0.0020	-99.9900	0.0060	0.0070	0.0030	0.0050	0.0060	0.0020	0.0020	-99.9900
1982	0.0090	0.0070	0.0010	-99.9900	0.0010	0.0060	0.0060	0.0060	0.0020	0.0010	0.0020	0.0030
1983	0.0020	-99.9900	0.0030	0.0380	0.0050	0.0040	0.0020	0.0040	0.0020	-99.9900	-99.9900	-99.9900
1984	0.0040	0.0020	0.0050	0.0070	0.0020	0.0070	0.0030	0.0030	0.0020	0.0030	0.0030	0.0030
1985	0.0060	0.0060	0.0380	0.0060	0.0060	0.0050	0.0020	0.0010	-99.9900	0.0010	0.0020	0.0070
1986	0.0030	0.0120	0.0160	0.0050	0.0050	0.0050	0.0020	0.0037	0.0030	0.0019	0.0026	0.0043
1987	0.0051	0.0041	0.0048	0.0049	0.0044	0.0043	0.0031	0.0040	0.0019	0.0019	0.0022	0.0021
1988	0.0061	0.0067	0.0056	0.0018	0.0041	0.0010	0.0021	0.0024	0.0014	0.0014	0.0028	0.0029
1989	0.0017	0.0048	0.0228	0.0019	0.0034	0.0046	0.0027	-99.9900	0.0023	0.0011	0.0026	0.0044
1990	0.0054	0.0015	0.0043	0.0119	0.0031	0.0027	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1991	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1992	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0040	0.0030	0.0025	0.0029	0.0036	0.0026	0.0056
1993	0.0040	0.0022	0.0091	0.0017	0.0019	0.0037	0.0041	0.0021	0.0021	0.0015	0.0028	0.0143
1994	0.0052	0.0084	0.0145	0.0031	0.0020	0.0030	0.0029	0.0014	0.0014	0.0021	0.0014	0.0033
1995	-99.9900	0.0040	0.0044	0.0053	0.0035	0.0071	0.0042	0.0054	0.0035	0.0018	0.0060	0.0048
1996	0.0048	0.0115	0.0061	0.0060	0.0041	0.0065	0.0062	-99.9900	0.0055	0.0048	0.0043	0.0039
1997	0.0042	0.0042	0.0033	-99.9900	-99.9900	-99.9900	0.0030	0.0060	0.0020	0.0020	0.0020	0.0020

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER 'OOSAO5MD0002 '

'Nickel Total' Parameter '100165'

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	0.0190	0.0080	0.0140	-99.9900	-99.9900	-99.9900	0.0060	0.0050	0.0090	0.0050	-99.9900	0.0040
1982	0.0050	0.0050	0.0050	-99.9900	-99.9900	-99.9900	0.0050	-99.9900	0.0040	0.0020	0.0020	0.0020
1983	0.0020	-99.9900	0.0020	0.0080	0.0040	0.0030	0.0030	0.0040	0.0030	0.0020	0.0020	0.0030
1984	0.0040	0.0040	0.0040	0.0050	0.0030	0.0060	0.0040	0.0040	0.0040	0.0050	0.0030	0.0070
1985	0.0030	0.0030	0.0030	0.0030	0.0040	0.0040	0.0040	0.0030	0.0030	0.0030	0.0030	0.0030
1986	0.0020	0.0030	0.0030	0.0030	0.0040	0.0040	0.0040	0.0033	0.0032	0.0045	0.0031	0.0030
1987	0.0025	0.0026	0.0021	0.0035	0.0038	0.0036	0.0035	0.0036	0.0033	0.0036	0.0025	0.0019
1988	0.0020	0.0020	0.0028	0.0016	0.0029	-99.9900	0.0034	0.0037	0.0037	0.0033	0.0033	0.0032
1989	0.0025	0.0030	0.0036	0.0019	0.0032	0.0031	0.0035	-99.9900	0.0026	0.0029	0.0034	0.0034
1990	0.0037	0.0030	0.0023	0.0049	0.0029	0.0116	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1991	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1992	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0038	0.0037	0.0039	0.0024	0.0040	0.0031	0.0031
1993	0.0025	0.0034	0.0027	0.0016	0.0022	0.0028	0.0031	0.0026	0.0020	0.0019	0.0019	0.0021
1994	0.0021	0.0023	0.0062	0.0019	0.0014	0.0027	0.0030	0.0026	0.0024	0.0024	0.0024	0.0025
1995	-99.9900	0.0021	0.0022	0.0021	0.0034	0.0035	0.0030	0.0027	0.0024	0.0020	0.0040	0.0018
1996	0.0018	0.0018	0.0020	0.0027	0.0026	0.0033	0.0033	-99.9900	0.0033	0.0032	0.0020	0.0015
1997	0.0016	0.0012	0.0011	-99.9900	-99.9900	-99.9900	0.0040	0.0060	0.0110	0.0110	0.0060	0.0030

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SA05MD0002 '

'Fecal Coliform ' Parameter Code '36011F '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1974	-99.9900	-99.9900	-99.9900	2.00	460.	100.	280.	90.0	-99.9900	40.0	-99.9900	24000.
1975	2400.	24000.	150000.	23.0	23.0	30.0	93.0	1600.	210.	1100.	220.	9000.
1976	11000.	28000.	15000.	-99.9900	50.0	20.0	220.	120.	90.0	60.0	2000.	1200.
1977	12800.	4500.	6800.	-99.9900	52.0	120.	165.	145.	115.	165.	100.	12.0
1978	4.00	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	2.00	-99.9900	6.00	2.00	-99.9900
1979	-99.9900	-99.9900	-99.9900	80.0	6.00	5.00	-99.9900	10.0	36.0	4.00	70.0	4.00
1980	4.00	2.00	-99.9900	-99.9900	8.00	7.00	-99.9900	6.00	5.00	4.00	4.00	4.00
1981	-99.9900	-99.9900	-99.9900	10.0	28.0	28.0	8.00	21.0	16.0	-99.9900	-99.9900	4.00
1982	-99.9900	-99.9900	4.00	190.	2.00	-99.9900	20.0	-99.9900	20.0	8.00	10.0	-99.9900
1983	-99.9900	-99.9900	2.00	150.	1 2.0	-99.9900	34.0	30.0	22.0	6.00	2.00	4.00
1984	6.00	4.00	2.00	6.00	4.00	32.0	46.0	28.0	10.0	76.0	-99.9900	30.0
1985	210.	11.0	14.0	10.0	-99.9900	68.0	10.0	17.0	6.00	18.0	-99.9900	2.00
1986	-99.9900	2.00	8.00	2.00	8.00	11.0	-99.9900	2.00	21.0	7.00	8.00	2.00
1987	5.00	132.	24.0	11.0	9.00	20.0	71.0	21.0	20.0	15.0	6.00	5.00
1988	4.00	16.0	2.00	6.00	10.0	38.0	18.0	17.0	6.00	11.0	2.00	4.00
1989	6.00	4.00	9.00	2.00	16.0	7.00	10.0	-99.9900	12.0	3.00	11.0	13.0
1990	17.0	4.00	12.0	40.0	7.00	39.0	7.00	35.0	6.00	57.0	-99.9900	11.0
1991	-99.9900	-99.9900	-99.9900	-99.9900	4.00	10.0	12.0	6.00	26.0	33.0	5.00	-99.9900
1992	-99.9900	-99.9900	-99.9900	30.0	12.0	7.00	15.0	2.00	16.0	68.0	13.0	-99.9900
1993	-99.9900	-99.9900	-99.9900	13.0	26.0	13.0	8.00	26.0	10.0	7.00	7.00	-99.9900

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SA05MD0002 '

'Mercury Total ' Parameter Code '80011P '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1979	-99.9900	-99.9900	-99.9900	0.0600	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1980	-99.9900	-99.9900	-99.9900	0.0300	-99.9900	0.0200	-99.9900	-99.9900	-99.9900	0.0200	0.0200	-99.9900
1981	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0300	0.0200	-99.9900	-99.9900	0.0200	0.0300	-99.9900
1982	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0300	0.0700	-99.9900
1983	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1984	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0300	-99.9900	-99.9900	-99.9900	-99.9900
1985	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1986	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1987	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0400	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1988	-99.9900	-99.9900	-99.9900	0.0300	0.0200	0.0200	0.0100	-99.9900	0.0100	-99.9900	0.0200	-99.9900
1989	-99.9900	-99.9900	-99.9900	-99.9900	0.0200	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1990	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1991	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1992	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0290	-99.9900	-99.9900
1993	-99.9900	-99.9900	0.0100	-99.9900	-99.9900	-99.9900	0.0130	-99.9900	0.0050	-99.9900	-99.9900	0.0130
1994	-99.9900	-99.9900	0.0100	0.0060	-99.9900	0.0090	0.0100	0.0080	-99.9900	0.0050	0.0050	-99.9900
1995	-99.9900	-99.9900	-99.9900	-99.9900	0.0070	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1996	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0070	0.0060	0.0050

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SA05MD0002 '

'Lead Total ' Parameter Code '82002P '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1981	0.0040	0.0060	-99.9900	-99.9900	0.0040	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1982	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1983	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0020	0.0010	-99.9900	-99.9900
1984	0.0020	-99.9900	-99.9900	0.0010	-99.9900	0.0010	-99.9900	-99.9900	-99.9900	0.0010	-99.9900	-99.9900
1985	-99.9900	0.0020	0.0070	0.0010	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1986	-99.9900	0.0020	0.0040	-99.9900	0.0010	-99.9900	0.0020	-99.9900	-99.9900	0.0010	0.0013	0.0012
1987	0.0016	0.0011	0.0019	0.0014	0.0014	0.0019	-99.9900	0.0015	0.0016	-99.9900	-99.9900	0.0011
1988	-99.9900	0.0008	0.0013	-99.9900	-99.9900	0.0015	0.0008	0.0009	-99.9900	-99.9900	-99.9900	-99.9900
1989	0.0024	0.0017	-99.9900	0.0010	0.0010	0.0012	0.0008	-99.9900	-99.9900	-99.9900	-99.9900	0.0030
1990	0.0012	0.0010	-99.9900	0.0011	0.0008	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1991	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1992	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0013	-99.9900	0.0007	-99.9900	-99.9900
1993	-99.9900	0.0022	-99.9900	-99.9900	-99.9900	0.0004	0.0002	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SA05MD0002 '

'245-T ' Parameter Code '18510L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1974	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1975	-99.9900	-99.9900	0.0080	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1976	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0200	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1977	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1978	-99.9900	-99.9900	-99.9900	0.0070	0.0010	-99.9900	-99.9900	-99.9900	0.0030	0.0050	-99.9900	0.0190
1979	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.0050	-99.9900	-99.9900	-99.9900
1980	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1981	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1982	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1983	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1984	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1985	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1986	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1987	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1988	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1989	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1990	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1991	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900
1992	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900

-99.9900 indicates missing data and less than values

'ASSINIBOINE RIVER NEAR KAMSACK ' STATION NUMBER '00SA05MD0002 '

'24-D ' Parameter Code '18500L '

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1974	-99.9900	-99.9900	-99.9900	-99.9900	0.0200	-99.9900	-99.9900	-99.9900	-99.9900	0.0400	0.0400	0.0700
1975	-99.9900	0.1300	0.0120	0.0700	-99.9900	-99.9900	-99.9900	-99.9900	0.0200	0.0100	-99.9900	-99.9900
1976	-99.9900	0.0300	-99.9900	-99.9900	0.0060	-99.9900	0.0500	-99.9900	0.0100	-99.9900	-99.9900	-99.9900
1977	-99.9900	0.0260	0.0900	-99.9900	0.0400	0.1000	0.0700	0.0800	0.0070	-99.9900	-99.9900	-99.9900
1978	-99.9900	-99.9900	-99.9900	0.0600	0.0150	0.0970	0.0500	0.0100	0.0200	0.0100	-99.9900	0.0090
1979	-99.9900	-99.9900	0.0060	0.3000	-99.9900	-99.9900	0.0500	0.0300	0.2000	-99.9900	-99.9900	-99.9900
1980	0.0050	-99.9900	-99.9900	0.0300	-99.9900	-99.9900	0.0700	-99.9900	0.0600	0.0100	-99.9900	-99.9900
1981	0.0080	-99.9900	-99.9900	-99.9900	-99.9900	0.3000	-99.9900	-99.9900	-99.9900	0.0400	-99.9900	-99.9900
1982	0.0300	0.0080	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.3000	-99.9900	0.0400	0.0300	-99.9900
1983	-99.9900	-99.9900	-99.9900	0.0500	-99.9900	-99.9900	0.2000	-99.9900	0.0140	0.0050	-99.9900	-99.9900
1984	0.0080	-99.9900	-99.9900	-99.9900	-99.9900	0.0100	0.0240	0.0200	-99.9900	-99.9900	0.0068	-99.9900
1985	-99.9900	0.0080	0.0180	-99.9900	-99.9900	0.1100	-99.9900	-99.9900	-99.9900	0.0800	-99.9900	-99.9900
1986	0.0300	0.0050	0.0220	0.0530	0.0490	0.1260	0.0390	0.0420	0.0100	0.2000	0.0080	-99.9900
1987	-99.9900	0.0170	0.0070	-99.9900	-99.9900	-99.9900	0.1000	-99.9900	-99.9900	0.0300	-99.9900	-99.9900
1988	0.0400	0.0400	0.0600	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.1800	-99.9900	-99.9900
1989	-99.9900	-99.9900	-99.9900	0.0600	-99.9900	0.0500	-99.9900	-99.9900	-99.9900	0.9200	-99.9900	-99.9900
1990	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.1200	-99.9900	-99.9900	-99.9900	-99.9900
1991	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	0.1200	-99.9900	-99.9900	0.0600	-99.9900	0.0800	-99.9900
1992	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900	-99.9900

-99.9900 indicates missing data and less than values

APPENDIX 2
TABLES OF NON-PARAMETRIC ANALYSISFOR THE ASSINIBOINE RIVER DATA

TDS* 00201L

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
MANN & KENDALL STAT.	-1.4873	-1.3873	.6303	1.2372	.0993	1.9379 *	-.4943	-1.1382	.3295	-.9886	1.2606	.0824
SPEARMAN STAT.	-1.3185	-1.1786	.8462	1.4747	.0515	2.3349	-.4588	-1.1637	.4395	-1.0420	1.1640	.0190
KENDALL COEFFICIENT	-.2833	-.2762	.1167	.2381	.0095	.3667	-.0882	-.2190	.0588	-.1765	.2333	.0147
SPEARMAN COEFFICIENT	-.3324	-.3107	.2206	.3786	.0143	.5294	-.1176	-.3071	.1127	-.2598	.2971	.0049
SEN LOWER CONF. INT.	-22.0000	-13.0253	-8.4730	-4.2334	-4.8487	-.4469	-11.5310	-14.3460	-10.4837	-44.7965	-8.3057	-6.9302
SEN ESTIMATED OF SLOPE	-6.2857	-7.3333	2.3909	6.5833	.0000	5.9375	-2.9911	-5.1429	1.0458	-10.8000	5.6250	1.1667
SEN UPPER CONF. INT.	2.5099	7.8558	20.3834	20.7081	8.3251	13.2947	4.1860	2.0000	10.3054	14.1003	16.8501	9.4791

OVER ALL RESULTS

SEASONAL KENDALL STATISTIC = .0259
MODIFY SEA. KEN. STATISTIC = .0194
VAN BELLE (HOMO) STATISTIC = 14.0512
VAN BELLE (TEND) STATISTIC = .0006
KENDALL COEFFICIENT = .0521
SPEARMAN COEFFICIENT = .0032
SEASONAL LOWER CONF. INT. = -3.2401
SEASONAL ESTIMATED OF SLOPE = .0000
SEASONAL UPPER CONF. INT. = 2.5898

* SIGNIFICANT AT 5 % LEVEL

Cond(F) 02041F

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
MANN & KENDALL STAT.	-.8563	-1.6208	.2472	.7204	-.1805	1.0805	-.5767	-1.2372	-.7415	-.8239	1.1131	1.3507
SPEARMAN STAT.	-.6248	-1.7941	.3527	.8581	-.1432	1.1894	-.4201	-1.2850	-.6547	-.9170	1.1810	1.3713
KENDALL COEFFICIENT	-.1500	-.3000	.0441	.1333	-.0333	.2000	-.1029	-.2381	-.1324	-.1471	.1912	.2500
SPEARMAN COEFFICIENT	-.1647	-.4324	.0907	.2235	-.0382	.3029	-.1078	-.3357	-.1667	-.2304	.2917	.3441
SEN LOWER CONF. INT.	-30.0000	-24.6149	-8.0000	-9.1604	-11.2153	-6.6570	-22.5697	-23.9419	-28.0372	-59.2636	-4.7195	-6.7003
SEN ESTIMATED OF SLOPE	-4.7560	-13.0536	1.8516	5.4943	-.1736	5.9167	-9.5208	-7.4444	-5.7500	-15.8000	7.1032	10.5833
SEN UPPER CONF. INT.	7.8230	2.5000	16.0000	29.4518	8.7249	15.3834	8.0000	6.1543	12.8713	20.0988	24.3556	23.6303

OVER ALL RESULTS

SEASONAL KENDALL STATISTIC = -.4154
MODIFY SEA. KEN. STATISTIC = -.3163
VAN BELLE (HOMO) STATISTIC = 11.1018
VAN BELLE (TEND) STATISTIC = .1938
KENDALL COEFFICIENT = .0245
SPEARMAN COEFFICIENT = -.0300
SEASONAL LOWER CONF. INT. = -5.0294
SEASONAL ESTIMATED OF SLOPE = -.6667
SEASONAL UPPER CONF. INT. = 2.6784

* SIGNIFICANT AT 5 % LEVEL

Turb.(F) 02073F

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
MANN & KENDALL STAT.	-.0495	1.4351	1.1706	-.6022	-.4955	-1.0392	.4064	.6124	.4502	1.2882	1.1010	1.3534
SPEARMAN STAT.	-.1160	1.3160	1.0764	-.4686	-.5204	-1.5403	.0991	.6307	.4320	1.0896	1.5020	1.9479
KENDALL COEFFICIENT	-.0095	.2762	.2167	-.1209	-.1048	-.2000	.0500	.1026	.0833	.2381	.2088	.2667
SPEARMAN COEFFICIENT	-.0321	.3429	.2765	-.1341	-.1429	-.3929	.0265	.1868	.1147	.2893	.3978	.4618
SEN LOWER CONF. INT.	-.4768	-.2076	-.2000	-4.1214	-2.3882	-2.2410	-.5839	-.5002	-.4907	-.2367	-.1827	-.2241
SEN ESTIMATED OF SLOPE	-.0029	.4286	.2800	-.7000	-.8000	-.6857	.2133	.6682	.1625	.3750	.2667	.2905
SEN UPPER CONF. INT.	.3818	1.0318	.7967	1.9462	.6738	1.1202	.9950	2.2310	.7500	.7513	1.0839	.6701

OVER ALL RESULTS

SEASONAL KENDALL STATISTIC = 1.6649
MODIFY SEA. KEN. STATISTIC = .9097
VAN BELLE (HOMO) STATISTIC = 7.9245
VAN BELLE (TEND) STATISTIC = 2.6423
KENDALL COEFFICIENT = -.0324
SPEARMAN COEFFICIENT = -.0224
SEASONAL LOWER CONF. INT. = -.0225
SEASONAL ESTIMATED OF SLOPE = .1857
SEASONAL UPPER CONF. INT. = .3518

* SIGNIFICANT AT 5 % LEVEL

B-diss 051050 (THE 2 YEARS MISSING DATA HAVE BEEN OMITTED)

MONTH	1	2	3	4	5	6	7	8	9	10	11	12
MANN & KENDALL STAT.	* -3.0200	* -2.0317	* -2.1801	* -2.6906	-1.7615	* -2.4709	* -2.7581	* -2.6944	* -2.0861	* -2.2324	* -2.0810	-1.9161
SPEARMAN STAT.	* -6.8790	* -2.9157	* -3.1736	* -3.7690	-1.9478	* -3.3644	* -3.7953	* -3.7296	* -3.0548	* -3.3309	* -2.9140	* -2.7516
KENDALL COEFFICIENT	-.6044	-.4066	-.4095	-.5604	-.3407	-.4945	-.5238	-.5897	-.4286	-.4476	-.4095	-.3846
SPEARMAN COEFFICIENT	-.8154	-.6440	-.6607	-.7363	-.4901	-.6967	-.7250	-.7473	-.6464	-.6786	-.6286	-.6220
SEN LOWER CONF. INT.	-.0202	-.0169	-.0136	-.0175	-.0134	-.0122	-.0112	-.0137	-.0120	-.0174	-.0097	-.0124
SEN ESTIMATED OF SLOPE	-.0141	-.0086	-.0091	-.0128	-.0100	-.0088	-.0081	-.0100	-.0077	-.0103	-.0059	-.0077
SEN UPPER CONF. INT.	-.0073	.0000	-.0026	-.0059	.0015	-.0017	-.0025	-.0051	.0000	-.0012	-.0004	.0031

OVER ALL RESULTS

SEASONAL KENDALL STATISTIC = -8.0239 *
MODIFY SEA. KEN. STATISTIC = -2.6908 *
VAN BELLE (HOMO) STATISTIC = 1.6789
VAN BELLE (TEND) STATISTIC = 64.9743 *
KENDALL COEFFICIENT = -.0511
SPEARMAN COEFFICIENT = -.0829
SEASONAL LOWER CONF. INT. = -.0101
SEASONAL ESTIMATED OF SLOPE = -.0091
SEASONAL UPPER CONF. INT. = -.0076

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            NO3+NO2   07106L

      MONTH                     1        2        3        4        5        6        7        8        9       10       11       12
                                                                                      *
MANN & KENDALL STAT.        .9005   1.6208    .4535    .8212    .0000   -.1519  -2.8455    .0000   -.3004    .0000   1.3644    .9499
                                                                                      *
SPEARMAN STAT.              .9540   1.5763    .5660    .6427   -.5774   -.4058  -6.1283    .5774   -.4906    .1721   1.2681   1.0525

KENDALL COEFFICIENT         .1667    .3000    .0735    .1648   -.3333   -.1429   -.8571    .3333   -.1429    .0667    .2821    .1618

SPEARMAN COEFFICIENT        .2471    .3882    .1446    .1824   -.5000   -.1786   -.9286    .5000   -.2143    .0857    .3571    .2623

SEN LOWER CONF. INT.       -.0075   -.0068   -.0193   -.0837 -99.9900   -.0100   -.0144 -99.9900   -.0038   -.0162   -.0008   -.0020

SEN ESTIMATED OF SLOPE      .0071    .0154    .0095    .0440   -.0055   -.0022   -.0065    .0072   -.0003    .0013    .0016    .0013

SEN UPPER CONF. INT.        .0229    .0394    .0403    .0931 -99.9900    .0084   -.0011 -99.9900    .0082    .0354    .0048    .0087

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =    1.8063
 MODIFY SEA. KEN.  STATISTIC =    1.2089
 VAN BELLE (HOMO)  STATISTIC =   16.2217
 VAN BELLE (TEND)  STATISTIC =     .5523
 KENDALL         COEFFICIENT =    -.3456
 SPEARMAN        COEFFICIENT =    -.5831
 SEASONAL LOWER   CONF. INT. =     .0000
 SEASONAL ESTIMATED OF SLOPE =     .0020
 SEASONAL UPPER   CONF. INT. =     .0060

                                                 * SIGNIFICANT AT 5 % LEVEL
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            NH3-tot   07503L

      MONTH                     1        2        3        4        5        6        7        8        9       10       11       12
                                                                                                                *
MANN & KENDALL STAT.       -.1642    .4454   1.0805    .2440  -1.6348   -.7184  -1.3060   -.1796    .2769  -2.2019   -.8541   -.9910
                                                                                                                *
SPEARMAN STAT.              .1753    .3232    .6939    .2743  -2.0960   -.7256  -1.3176    .0516    .2440  -2.5685   -.8463   -.9594

KENDALL COEFFICIENT        -.0330    .0857    .2000    .0513   -.3818   -.1556   -.2727   -.0222    .0303   -.4505   -.1795   -.1810

SPEARMAN COEFFICIENT        .0505    .0893    .1824    .0824   -.5727   -.2485   -.3846    .0182    .0769   -.5956   -.2473   -.2571

SEN LOWER CONF. INT.       -.0161   -.0162   -.0081   -.0219   -.0197   -.0148   -.0144   -.0095   -.0061   -.1056   -.0134   -.0156

SEN ESTIMATED OF SLOPE     -.0016    .0036    .0041    .0032   -.0066   -.0023   -.0047   -.0003    .0001   -.0412   -.0045   -.0057

SEN UPPER CONF. INT.        .0213    .0214    .0123    .0382    .0021    .0022    .0021    .0036    .0011   -.0002    .0040    .0095

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =   -1.4873
 MODIFY SEA. KEN.  STATISTIC =   -1.3089
 VAN BELLE (HOMO)  STATISTIC =   10.0126
 VAN BELLE (TEND)  STATISTIC =    3.0032
 KENDALL         COEFFICIENT =    -.3027
 SPEARMAN        COEFFICIENT =    -.4448
 SEASONAL LOWER   CONF. INT. =    -.0057
 SEASONAL ESTIMATED OF SLOPE =    -.0020
 SEASONAL UPPER   CONF. INT. =     .0003

                                                 * SIGNIFICANT AT 5 % LEVEL
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             TN*      07602L

          MONTH              1        2        3        4        5        6        7        8        9       10       11       12

MANN & KENDALL STAT.     .4502    .6303    .4119   1.2606    .6760    .1352   -.0451   -.4454    .2472   -.9482   1.6477   1.8949
                                                                                                                                *
SPEARMAN STAT.           .5449    .8225    .8657    .9782    .6939    .4883    .3984    .2452    .6844   -.7243   2.1073   2.2802

KENDALL COEFFICIENT      .0833    .1167    .0735    .2333    .1333    .0333    .0000   -.0857    .0441   -.1765    .2941    .3382

SPEARMAN COEFFICIENT     .1441    .2147    .2181    .2529    .1824    .1294    .1059    .0679    .1740   -.1838    .4779    .5074

SEN LOWER CONF. INT.    -.0445   -.0464   -.0395   -.0144   -.0341   -.0511   -.0439   -.0447   -.0303   -.0855   -.0100   -.0047

SEN ESTIMATED OF SLOPE   .0161    .0258    .0152    .0577    .0156    .0142   -.0010   -.0140    .0057   -.0358    .0371    .0608

SEN UPPER CONF. INT.     .0847    .1131    .0953    .1198    .0472    .0653    .0485    .0298    .0390    .0292    .0900    .0975

 OVER ALL RESULTS


 SEASONAL KENDALL  STATISTIC =    1.7497
 MODIFY SEA. KEN.  STATISTIC =     .7429
 VAN BELLE (HOMO)  STATISTIC =    7.3843
 VAN BELLE (TEND)  STATISTIC =    2.9160
 KENDALL         COEFFICIENT =    -.1818
 SPEARMAN        COEFFICIENT =    -.2625
 SEASONAL LOWER   CONF. INT. =    -.0020
 SEASONAL ESTIMATED OF SLOPE =     .0155
 SEASONAL UPPER   CONF. INT. =     .0306


                                               * SIGNIFICANT AT 5 % LEVEL



             pH(F)    10301F

          MONTH              1        2        3        4        5        6        7        8        9       10       11       12

MANN & KENDALL STAT.     .2720    .7730  -1.1600    .0908    .0459  -1.0000  -1.3628  -1.3065    .0418   -.4179    .4564   -.9504

SPEARMAN STAT.          -.0220    .7521  -1.0000    .0881   -.0771  -1.0394  -1.2686  -1.4263    .1806   -.5367    .4491   -.8862

KENDALL COEFFICIENT      .0333    .1500   -.1912    .0333    .0000   -.2000   -.2353   -.2762    .0147   -.1029    .0735   -.1618

SPEARMAN COEFFICIENT    -.0059    .1971   -.2500    .0235   -.0206   -.2676   -.3113   -.3679    .0466   -.1373    .1152   -.2230

SEN LOWER CONF. INT.    -.0176   -.0292   -.0566   -.0252   -.0246   -.0317   -.0500   -.0450   -.0195   -.0216   -.0213   -.0369

SEN ESTIMATED OF SLOPE   .0020    .0075   -.0100    .0000    .0000   -.0051   -.0219   -.0118    .0000   -.0004    .0032   -.0092

SEN UPPER CONF. INT.     .0362    .0327    .0239    .0438    .0252    .0119    .0121    .0036    .0196    .0189    .0358    .0141

 OVER ALL RESULTS


 SEASONAL KENDALL  STATISTIC =   -1.3112
 MODIFY SEA. KEN.  STATISTIC =    -.9548
 VAN BELLE (HOMO)  STATISTIC =    6.1788
 VAN BELLE (TEND)  STATISTIC =    1.7009
 KENDALL         COEFFICIENT =     .2928
 SPEARMAN        COEFFICIENT =     .4271
 SEASONAL LOWER   CONF. INT. =    -.0100
 SEASONAL ESTIMATED OF SLOPE =    -.0011
 SEASONAL UPPER   CONF. INT. =     .0000


                                               * SIGNIFICANT AT 5 % LEVEL
          DO        08101F

        MONTH              1        2        3        4        5        6        7        8        9       10       11       12

                                                                                                    *
MANN & KENDALL STAT.    .3609   -.3163   -.2472   1.5381   -.4465   -.6960  -1.5254    .0496  -2.5583  -1.5742    .4545  -1.3636
                                                                                                    *
SPEARMAN STAT.          .1652   -.5563   -.3335   1.4384   -.3755   -.6274  -1.2575    .2972  -3.1009  -1.6147    .2378  -1.2908

KENDALL COEFFICIENT     .0667   -.0833   -.0441    .3000   -.0857   -.1238   -.2794    .0095   -.4559   -.2794    .0588   -.2647

SPEARMAN COEFFICIENT    .0441   -.1471   -.0858    .3588   -.1036   -.1716   -.3088    .0821   -.6250   -.3848    .0613   -.3162

SEN LOWER CONF. INT.   -.2000   -.2000   -.3127   -.0684   -.2314   -.1333   -.2337   -.1338   -.2425   -.2268   -.1089   -.3854

SEN ESTIMATED OF SLOPE  .0350   -.0122   -.0629    .1300   -.0333   -.0750   -.1000    .0000   -.1323   -.1000    .0333   -.1780

SEN UPPER CONF. INT.    .2394    .2119    .1910    .3000    .1000    .1000    .0600    .2025   -.0288    .0331    .3206    .0703

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =   -1.9295
 MODIFY SEA. KEN.  STATISTIC =   -1.5086
 VAN BELLE (HOMO)  STATISTIC =   13.4261
 VAN BELLE (TEND)  STATISTIC =    3.3331
 KENDALL          COEFFICIENT =     .3032
 SPEARMAN         COEFFICIENT =     .4453
 SEASONAL LOWER   CONF. INT. =    -.1000
 SEASONAL ESTIMATED OF SLOPE =    -.0500
 SEASONAL UPPER   CONF. INT. =     .0000


                                        * SIGNIFICANT AT 5 % LEVEL
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          NFR       10401L

        MONTH              1        2        3        4        5        6        7        8        9       10       11       12

MANN & KENDALL STAT.   -.6760   -.0905   -.3301   -.1352    .2707   -.8104   1.7330    .9426   1.4436   1.0324    .7218    .4952
                                                                                *
SPEARMAN STAT.         -.4658   -.1101   -.6448   -.2315    .0550   -.8581   2.2070   1.0313   1.3185    .8657    .8938    .7644

KENDALL COEFFICIENT    -.1333   -.0167   -.0588   -.0167    .0333   -.1500    .3088    .1810    .2500    .1912    .1167    .0882

SPEARMAN COEFFICIENT   -.1235   -.0294   -.1642   -.0618    .0147   -.2235    .4951    .2750    .3324    .2181    .2324    .1936

SEN LOWER CONF. INT.   -.6729   -.5865   -.6667  -3.5497  -1.9778  -3.2191   -.1528   -.4295   -.1552   -.2730   -.2960   -.5322

SEN ESTIMATED OF SLOPE -.2733    .0000   -.0598   -.3417    .1278   -.6282   1.0598    .4667    .3000    .1354    .3359    .0783

SEN UPPER CONF. INT.    .3685    .5000    .5000   2.6894   2.0787    .9458   1.9839   1.6376   1.0000    .8419   1.2000    .9347

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =    1.3467
 MODIFY SEA. KEN.  STATISTIC =     .7036
 VAN BELLE (HOMO)  STATISTIC =    7.3694
 VAN BELLE (TEND)  STATISTIC =    1.7611
 KENDALL          COEFFICIENT =    -.0820
 SPEARMAN         COEFFICIENT =    -.0939
 SEASONAL LOWER   CONF. INT. =    -.0667
 SEASONAL ESTIMATED OF SLOPE =     .1333
 SEASONAL UPPER   CONF. INT. =     .3529


                                        * SIGNIFICANT AT 5 % LEVEL
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             Na-diss   11103L

        MONTH              1       2       3       4       5       6       7       8       9      10      11      12

                                                                                   *
MANN & KENDALL STAT.  -1.3971  -.8563   .2253  1.6208   .8413   .9005  -.9886 -2.0290  -.7009 -1.5653   .2886  -.4943
                                                                                   *
SPEARMAN STAT.        -1.3054  -.7872   .3761  1.9637   .7223   .7521  -.9480 -2.1621  -.7343 -1.7500   .4782  -.6448

KENDALL COEFFICIENT    -.2500  -.1500   .0500   .3000   .1619   .1667  -.1765  -.3905  -.1324  -.2794   .0588  -.0882

SPEARMAN COEFFICIENT   -.3294  -.2059   .1000   .4647   .1964   .1971  -.2377  -.5143  -.1863  -.4118   .1225  -.1642

SEN LOWER CONF. INT.  -2.5617 -2.3224 -1.2500  -.2575  -.5301  -.3192 -1.9826 -2.0868 -1.9737 -9.1350 -1.3693 -1.5527

SEN ESTIMATED OF SLOPE -.5625  -.5721   .1866   .6167   .3250   .3792  -.4167 -1.1000  -.3604 -2.4625   .2250  -.3512

SEN UPPER CONF. INT.     .7781  1.2401  1.9559  2.2192  1.0202  1.0000   .4363   .0216  1.0957  1.1624  2.6877  1.3360

 OVER ALL RESULTS


 SEASONAL KENDALL  STATISTIC =  -1.2294
 MODIFY SEA. KEN.  STATISTIC =   -.7680
 VAN BELLE (HOMO)  STATISTIC =  13.8060
 VAN BELLE (TEND)  STATISTIC =   1.4387
 KENDALL         COEFFICIENT =    .1113
 SPEARMAN        COEFFICIENT =    .1313
 SEASONAL LOWER   CONF. INT. =   -.4675
 SEASONAL ESTIMATED OF SLOPE =   -.1472
 SEASONAL UPPER   CONF. INT. =    .1167

                                          * SIGNIFICANT AT 5 % LEVEL
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             P-tot    15406L

        MONTH              1       2       3       4       5       6       7       8       9      10      11      12


MANN & KENDALL STAT.   1.6721  1.5308   .0824  1.1267   .7662  -.1805 -1.4855  -.4955   .0413 -1.3070  1.1983  1.7768

SPEARMAN STAT.         1.4114  1.7941   .3623  1.2534   .5336   .0110 -1.4149  -.4675   .1045 -1.4384  1.3131  1.8778

KENDALL COEFFICIENT     .3167   .2833   .0147   .2000   .1333  -.0333  -.2500  -.1048   .0294  -.2333   .2206   .3235

SPEARMAN COEFFICIENT    .3529   .4324   .0931   .3176   .1612   .0029  -.3431  -.1286   .0270  -.3588   .3211   .4363

SEN LOWER CONF. INT.   -.0006  -.0014  -.0045  -.0039  -.0034  -.0050  -.0117  -.0127  -.0041  -.0531  -.0021  -.0003

SEN ESTIMATED OF SLOPE  .0023   .0016   .0002   .0054   .0019  -.0003  -.0042  -.0020   .0000  -.0065   .0015   .0023

SEN UPPER CONF. INT.    .0046   .0047   .0080   .0138   .0079   .0076   .0013   .0051   .0037   .0019   .0050   .0049

 OVER ALL RESULTS


 SEASONAL KENDALL  STATISTIC =   1.3741
 MODIFY SEA. KEN.  STATISTIC =    .9364
 VAN BELLE (HOMO)  STATISTIC =  13.9285
 VAN BELLE (TEND)  STATISTIC =   1.8614
 KENDALL         COEFFICIENT =    .0340
 SPEARMAN        COEFFICIENT =    .0791
 SEASONAL LOWER   CONF. INT. =   -.0003
 SEASONAL ESTIMATED OF SLOPE =    .0006
 SEASONAL UPPER   CONF. INT. =    .0019

                                          * SIGNIFICANT AT 5 % LEVEL
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```
          SO4-diss  16304L

     MONTH              1        2        3        4        5        6        7        8        9       10       11       12

MANN & KENDALL STAT.    .1801   -.9905    .9005    .8563    .1485   1.6285   -.8253  -1.3362    .0824  -1.0710   1.1956    .7833

SPEARMAN STAT.          .1211   -.9782    .8819    .9058    .1934   1.8854   -.6745  -1.3628    .1710  -1.0950   1.2686   1.0210

KENDALL COEFFICIENT     .0333   -.1833    .1667    .1500    .0286    .3167   -.1618   -.2571    .0147   -.1912    .2059    .1471

SPEARMAN COEFFICIENT    .0324   -.2529    .2294    .2353    .0536    .4500   -.1716   -.3536    .0441   -.2721    .3113    .2549

SEN LOWER CONF. INT.  -7.0000  -7.2556  -4.2556  -2.4342  -4.6850  -1.2838  -5.0894  -6.3810  -6.6450 -20.1961  -3.5464  -2.4426

SEN ESTIMATED OF SLOPE  .3333  -2.4000   2.6083   1.8250    .4000   3.8889  -1.8397  -2.0833    .3750  -5.5500   4.8365   2.7946

SEN UPPER CONF. INT.   7.0993   4.0249  11.1271   7.9221   5.0046   6.6667   2.6250    .9303   5.7897   8.8963   9.8943   8.1284

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =     .4691
 MODIFY SEA. KEN.  STATISTIC =     .2713
 VAN BELLE (HOMO)  STATISTIC =   10.6942
 VAN BELLE (TEND)  STATISTIC =     .2008
 KENDALL         COEFFICIENT =     .0542
 SPEARMAN        COEFFICIENT =     .0712
 SEASONAL LOWER   CONF. INT. =   -1.0597
 SEASONAL ESTIMATED OF SLOPE =     .4167
 SEASONAL UPPER   CONF. INT. =    1.9049

                                       * SIGNIFICANT AT 5 % LEVEL
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          Cl-diss   17206L

     MONTH              1        2        3        4        5        6        7        8        9       10       11       12

MANN & KENDALL STAT.   -.8104   -.4056    .3602   1.8528    .7423    .0000   -.5767  -1.2372   -.6591  -1.1956    .4502   1.0710

SPEARMAN STAT.         -.9298   -.2870    .2537   1.9165    .7360    .1321   -.7143  -1.4263   -.7143  -1.2355    .5222    .7744

KENDALL COEFFICIENT    -.1500   -.0833    .0667    .3167    .1429    .0000   -.1029   -.2381   -.1176   -.2206    .0833    .1912

SPEARMAN COEFFICIENT   -.2412   -.0765    .0676    .4559    .2000    .0353   -.1814   -.3679   -.1814   -.3039    .1382    .1961

SEN LOWER CONF. INT.  -1.8209  -1.6898  -1.0153   -.0223   -.4702   -.4236  -1.2837  -2.1236  -1.3587  -7.6810  -1.1008   -.3791

SEN ESTIMATED OF SLOPE -.3583   -.3302    .2983    .4833    .2667   -.0030   -.1100   -.8167   -.2955  -1.9155    .5300    .6956

SEN UPPER CONF. INT.   1.6831   1.1073   2.0307   1.8921    .9270   1.0077    .4701    .4401    .7592    .8539   2.4771   1.8244

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =    -.1405
 MODIFY SEA. KEN.  STATISTIC =    -.0719
 VAN BELLE (HOMO)  STATISTIC =    9.9979
 VAN BELLE (TEND)  STATISTIC =     .0139
 KENDALL         COEFFICIENT =     .0285
 SPEARMAN        COEFFICIENT =     .0441
 SEASONAL LOWER   CONF. INT. =    -.2393
 SEASONAL ESTIMATED OF SLOPE =    -.0171
 SEASONAL UPPER   CONF. INT. =     .2794

                                       * SIGNIFICANT AT 5 % LEVEL
          A-BHC     18075L     ( THE 4 YEARS MISSING DATA HAVE BEEN OMITTED )

     MONTH                      1        2        3        4        5        6        7        8        9       10       11       12

                          *                          *        *                          *        *        *        *        *
MANN & KENDALL STAT.      -2.0667  -1.8937    .5165  -1.9766  -2.6941  -1.3732  -1.2824  -2.9122  -2.8117  -2.8713  -2.2975  -2.3689
                          *        *                 *        *                          *        *        *        *        *
SPEARMAN STAT.            -3.6522  -2.7201    .8226  -2.7584  -4.1332  -2.0005   -.9556  -3.3508  -3.1135  -4.2910  -2.8643  -3.7238

KENDALL COEFFICIENT        -.6000   -.4505    .1818   -.4848   -.5238   -.3590   -.2088   -.5758   -.5238   -.6667   -.3939   -.5152

SPEARMAN COEFFICIENT       -.7727   -.6176    .2517   -.6573   -.7536   -.5165   -.2659   -.7273   -.6536   -.7912   -.6713   -.7622

SEN LOWER CONF. INT.       -.0006   -.0003   -.0002   -.0005   -.0006   -.0006   -.0005   -.0012   -.0011   -.0010   -.0006   -.0010

SEN ESTIMATED OF SLOPE     -.0003   -.0001    .0000   -.0002   -.0004   -.0002   -.0002   -.0007   -.0008   -.0003   -.0002   -.0005

SEN UPPER CONF. INT.        .0000    .0000    .0002    .0000    .0000    .0001    .0001   -.0004   -.0002   -.0002    .0000    .0000

OVER ALL RESULTS

SEASONAL KENDALL  STATISTIC =  -6.9949  *
MODIFY SEA. KEN.  STATISTIC =  -3.3248  *
VAN BELLE (HOMO)  STATISTIC =  10.2133
VAN BELLE (TEND)  STATISTIC =  48.1271  *
KENDALL         COEFFICIENT =    .1574
SPEARMAN        COEFFICIENT =    .2375
SEASONAL LOWER   CONF. INT. =   -.0003
SEASONAL ESTIMATED OF SLOPE =   -.0003
SEASONAL UPPER   CONF. INT. =   -.0002       * SIGNIFICANT AT 5 % LEVEL
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          Ca-diss   20101L

     MONTH                      1        2        3        4        5        6        7        8        9       10       11       12

                                                                                                                             *
MANN & KENDALL STAT.       -.4511   -.7204    .2722    .4502   -.4454    .9464    .2472   -.2474    .9886    .4535   -.7833  -2.0596
                                                                                                                             *
SPEARMAN STAT.             -.3649   -.2870    .4096    .4770   -.4807   1.1514    .4395   -.4017    .9687    .3143   -.8555  -2.1696

KENDALL COEFFICIENT        -.1000   -.1333    .0500    .0833   -.0857    .1833    .0441   -.0476    .1765    .0882   -.1471   -.3676

SPEARMAN COEFFICIENT       -.0971   -.0765    .1088    .1265   -.1321    .2941    .1127   -.1107    .2426    .0809   -.2157   -.4853

SEN LOWER CONF. INT.      -4.4077  -3.4833  -3.9435  -1.0461  -1.1803   -.7035   -.9404  -1.5965   -.5779  -1.0000  -3.1105  -3.2106

SEN ESTIMATED OF SLOPE     -.2917   -.4365    .1250    .4233   -.4154    .3565    .1694   -.2833    .4550    .2225   -.7134  -1.8333

SEN UPPER CONF. INT.       3.7223   2.2170   4.4169   2.2463    .7602   1.4264    .9072    .9350   1.9373   2.4770   1.0652   -.0677

OVER ALL RESULTS


SEASONAL KENDALL  STATISTIC =   -.3931
MODIFY SEA. KEN.  STATISTIC =   -.3182
VAN BELLE (HOMO)  STATISTIC =   8.1027
VAN BELLE (TEND)  STATISTIC =    .1517
KENDALL         COEFFICIENT =    .0834
SPEARMAN        COEFFICIENT =    .0237
SEASONAL LOWER   CONF. INT. =   -.5028
SEASONAL ESTIMATED OF SLOPE =   -.0786
SEASONAL UPPER   CONF. INT. =    .3352


                                         * SIGNIFICANT AT 5 % LEVEL
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        MN-DISS  251040    ( THE 6 YEARS MISSING DATA HAVE BEEN OMITTED )

     MONTH                    1        2        3        4        5        6        7        8        9       10       11       12

MANN & KENDALL STAT.     -.0778  -1.5205   -.0894    .2062   -.4811    .9869   -.0687  -1.0120   -.5449  -1.0972    .7561   1.3060

SPEARMAN STAT.            .0546  -1.7000    .0171    .0664   -.4012   1.3668   -.2663   -.9750   -.4129  -1.3176    .6785   1.2072

KENDALL COEFFICIENT      -.0182   -.3778   -.0222    .0303   -.1212    .2088   -.0303   -.2364   -.1273   -.2424    .1818    .2727

SPEARMAN COEFFICIENT      .0182   -.5152    .0061    .0210   -.1259    .3670   -.0839   -.3091   -.1364   -.3846    .2098    .3566

SEN LOWER CONF. INT.     -.0700   -.1805   -.0752   -.0053   -.0148   -.0108   -.0139   -.0296   -.0449   -.0247   -.0086   -.0031

SEN ESTIMATED OF SLOPE   -.0007   -.0450   -.0019    .0001   -.0029    .0070   -.0001   -.0040   -.0092   -.0053    .0032    .0059

SEN UPPER CONF. INT.      .0342    .0263    .0394    .0112    .0083    .0392    .0168    .0128    .0128    .0105    .0200    .0254

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =    -.2476
 MODIFY SEA. KEN.  STATISTIC =    -.2210
 VAN BELLE (HOMO)  STATISTIC =    8.1576
 VAN BELLE (TEND)  STATISTIC =     .2232
 KENDALL         COEFFICIENT =    -.1371
 SPEARMAN        COEFFICIENT =    -.2127
 SEASONAL LOWER   CONF. INT. =    -.0044
 SEASONAL ESTIMATED OF SLOPE =    -.0001
 SEASONAL UPPER   CONF. INT. =     .0035      * SIGNIFICANT AT 5 % LEVEL



        FE-DISS  261040    ( THE 6 YEARS MISSING DATA HAVE BEEN OMITTED )

     MONTH                    1        2        3        4        5        6        7        8        9       10       11       12

                                                                *        *
MANN & KENDALL STAT.     -.1648  -1.4647   -.4508    .7561  -2.0000  -2.4777  -1.7143  -1.5600  -1.7903    .8571  -1.2603   -.8321
                                                                *        *
SPEARMAN STAT.            .1913  -1.3021   -.5410    .7022  -2.6087  -3.6261  -1.7421  -1.4549  -1.5826    .7500  -1.1802   -.7500

KENDALL COEFFICIENT       .0182   -.3333   -.1556    .1515   -.5455   -.6264   -.4545   -.3818   -.4545    .2424   -.2727   -.1818

SPEARMAN COEFFICIENT      .0636   -.4182   -.1879    .2168   -.6364   -.7231   -.4825   -.4364   -.4476    .2308   -.3497   -.2308

SEN LOWER CONF. INT.     -.0041   -.0060   -.0052   -.0038   -.0024   -.0027   -.0043   -.0043   -.0045   -.0011   -.0052   -.0094

SEN ESTIMATED OF SLOPE    .0000   -.0013   -.0013    .0020   -.0005   -.0010   -.0027   -.0022   -.0026    .0022   -.0017   -.0010

SEN UPPER CONF. INT.      .0027    .0009    .0054    .0062    .0000    .0000    .0000    .0000    .0000    .0045    .0020    .0051

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =   -3.5560  *
 MODIFY SEA. KEN.  STATISTIC =   -2.1505  *
 VAN BELLE (HOMO)  STATISTIC =   12.4751
 VAN BELLE (TEND)  STATISTIC =   12.2043  *
 KENDALL         COEFFICIENT =    -.1036
 SPEARMAN        COEFFICIENT =    -.1431
 SEASONAL LOWER   CONF. INT. =    -.0019
 SEASONAL ESTIMATED OF SLOPE =    -.0009
 SEASONAL UPPER   CONF. INT. =     .0000      * SIGNIFICANT AT 5 % LEVEL
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          COPPER total 29005P( THE 1 YEAR MISSING DATA HAS BEEN OMITTED)


    MONTH                    1        2        3        4        5        6        7        8        9       10       11       12
                                                        *        *
MANN & KENDALL STAT.   -1.2667  -1.0475  -1.2667  -2.1415  -2.3707   -.9015   -.3608    .1864   -.4513    .0000    .9401   -.5025
                                                        *        *
SPEARMAN STAT.          -.9049  -1.2187  -1.2920  -3.4915  -3.4484   -.9452   -.6005    .1825   -.5071   -.1031    .7071   -.3102

KENDALL COEFFICIENT     -.2747   -.2308   -.2527   -.4505   -.4725   -.2381   -.1810    .0000   -.1048   -.0286    .2308   -.0667

SPEARMAN COEFFICIENT    -.2527   -.3319   -.3495   -.7099   -.7055   -.2536   -.1643    .0549   -.1393   -.0286    .2000   -.0857

SEN LOWER CONF. INT.    -.0005   -.0003   -.0004   -.0006   -.0004   -.0001   -.0001   -.0001   -.0001   -.0002   -.0001   -.0001

SEN ESTIMATED OF SLOPE  -.0001   -.0001   -.0001   -.0003   -.0002    .0000    .0000    .0000    .0000    .0000    .0000    .0000

SEN UPPER CONF. INT.     .0000    .0001    .0000    .0000    .0000    .0001    .0001    .0002    .0001    .0002    .0002    .0001

 OVER ALL RESULTS


 SEASONAL KENDALL  STATISTIC =   -2.6387  *
 MODIFY SEA. KEN.  STATISTIC =   -1.4902
 VAN BELLE (HOMO)  STATISTIC =    9.8032
 VAN BELLE (TEND)  STATISTIC =    7.0270  *
 KENDALL         COEFFICIENT =    -.1106
 SPEARMAN        COEFFICIENT =    -.1415
 SEASONAL LOWER   CONF. INT. =    -.0001
 SEASONAL ESTIMATED OF SLOPE =     .0000
 SEASONAL UPPER   CONF. INT. =     .0000

                                          * SIGNIFICANT AT 5 % LEVEL
```

```
        .   ZINC tot  30005P   ( THE 1 YEAR MISSING DATA HAS BEEN OMITTED )


    MONTH                    1        2        3        4        5        6        7        8        9       10       11       12

MANN & KENDALL STAT.    -.7138   -.8212    .8413  -1.3060  -1.3769  -1.1921   1.5076   -.7348    .1111   1.2098   1.1733    .1834

SPEARMAN STAT.          -.8216   -.8381   1.0458  -1.3459  -1.2187   -.7497   1.0750   -.5543    .2673   1.1291    .7722    .1459

KENDALL COEFFICIENT     -.1648   -.1648    .1619   -.3030   -.2967   -.2000    .2762   -.1795    .0549    .2308    .2308    .0513

SPEARMAN COEFFICIENT    -.2308   -.2352    .2786   -.3916   -.3319   -.2036    .2857   -.1648    .0769    .3099    .2176    .0440

SEN LOWER CONF. INT.    -.0003   -.0010   -.0006   -.0013   -.0004   -.0004    .0000   -.0004   -.0001    .0000   -.0001   -.0003

SEN ESTIMATED OF SLOPE  -.0001   -.0002    .0002   -.0004   -.0002   -.0002    .0001   -.0001    .0000    .0001    .0001    .0000

SEN UPPER CONF. INT.     .0002    .0004    .0008    .0002    .0001    .0001    .0002    .0002    .0002    .0002    .0002    .0003

 OVER ALL RESULTS


 SEASONAL KENDALL  STATISTIC =    -.2075
 MODIFY SEA. KEN.  STATISTIC =    -.1631
 VAN BELLE (HOMO)  STATISTIC =   12.5089
 VAN BELLE (TEND)  STATISTIC =     .1042
 KENDALL         COEFFICIENT =    -.2612
 SPEARMAN        COEFFICIENT =    -.3764
 SEASONAL LOWER   CONF. INT. =    -.0001
 SEASONAL ESTIMATED OF SLOPE =     .0000
 SEASONAL UPPER   CONF. INT. =     .0000

                                          * SIGNIFICANT AT 5 % LEVEL
```

```
         Nickel tot 28002P   ( THE 1 YEAR MISSING DATA HAS BEEN OMITTED )

      MONTH                   1        2        3        4        5        6        7        8        9       10       11       12

                              *        *        *                 *                 *
MANN & KENDALL STAT.    -2.6018  -3.3837  -2.3316  -1.7265  -2.4962  -1.4434  -2.2642  -1.2402  -1.5468   -.4480   1.4356  -1.6507
                              *        *        *        *        *                 *
SPEARMAN STAT.          -2.6583  -4.6543  -2.3744  -2.3804  -3.0339  -1.2896  -2.3306  -1.2619  -1.2543   -.3363    .9727  -2.0228

KENDALL COEFFICIENT      -.4945   -.6923   -.4667   -.3636   -.5455   -.3030   -.4667   -.2727   -.2762   -.0857    .2527   -.3524

SPEARMAN COEFFICIENT     -.6088   -.8022   -.5500   -.6014   -.6923   -.3776   -.5429   -.3706   -.3286   -.0929    .2703   -.4893

SEN LOWER CONF. INT.     -.0004   -.0005   -.0004   -.0006   -.0003   -.0002   -.0002   -.0002   -.0002   -.0002    .0000   -.0002

SEN ESTIMATED OF SLOPE   -.0002   -.0002   -.0002   -.0002   -.0001   -.0001   -.0001   -.0001   -.0001    .0000    .0001   -.0001

SEN UPPER CONF. INT.      .0000   -.0001    .0000    .0000    .0000    .0000    .0000    .0001    .0000    .0002    .0002    .0000

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =   -5.6102  *
 MODIFY SEA. KEN.  STATISTIC =   -2.7981  *
 VAN BELLE (HOMO)  STATISTIC =   16.6615
 VAN BELLE (TEND)  STATISTIC =   32.3320  *
 KENDALL        COEFFICIENT =      .0030
 SPEARMAN       COEFFICIENT =      .0262
 SEASONAL LOWER   CONF. INT. =    -.0001
 SEASONAL ESTIMATED OF SLOPE =    -.0001
 SEASONAL UPPER   CONF. INT. =    -.0001

                                          * SIGNIFICANT AT 5 % LEVEL


            F.COLI    36011F

      MONTH                   1        2        3        4        5        6        7        8        9       10       11       12

MANN & KENDALL STAT.     -.3682   -.3608   -.5558    .7309   -.8066   -.5617  -1.3704  -1.7127  -1.7582   -.2925  -1.4288  -1.3334

SPEARMAN STAT.           -.7288   -.6139   -.4675   1.1280  -1.0765   -.6368  -1.5562  -2.0679  -2.0125   -.4556  -1.4270  -1.0764

KENDALL COEFFICIENT      -.0833   -.0667   -.0476    .1765   -.1111   -.0877   -.2105   -.3072   -.2947   -.0421   -.1895   -.1667

SPEARMAN COEFFICIENT     -.1912   -.1679   -.1286    .2714   -.2526   -.1526   -.3444   -.4592   -.4286   -.1068   -.3188   -.2765

SEN LOWER CONF. INT.  -174.8732-531.1462-958.2097  -1.3075  -2.8143  -3.6294 -10.0152  -7.4779  -4.6667  -4.0000  -5.3321-112.1372

SEN ESTIMATED OF SLOPE    .0000    .0000   -.2000    .2308   -.6667   -.7500  -2.3556  -3.0000  -1.1270   -.1627   -.6333   -.6833

SEN UPPER CONF. INT.      .4291    .2364    .8546   1.5515    .5443    .8432    .4171    .3348    .1025   1.3399    .0000    .0964

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =   -2.9174  *
 MODIFY SEA. KEN.  STATISTIC =   -1.2722
 VAN BELLE (HOMO)  STATISTIC =    5.8496
 VAN BELLE (TEND)  STATISTIC =    8.0332  *
 KENDALL        COEFFICIENT =      .0342
 SPEARMAN       COEFFICIENT =      .0541
 SEASONAL LOWER   CONF. INT. =   -1.3333
 SEASONAL ESTIMATED OF SLOPE =     -.6077
 SEASONAL UPPER   CONF. INT. =      .0000      * SIGNIFICANT AT 5 % LEVEL
```

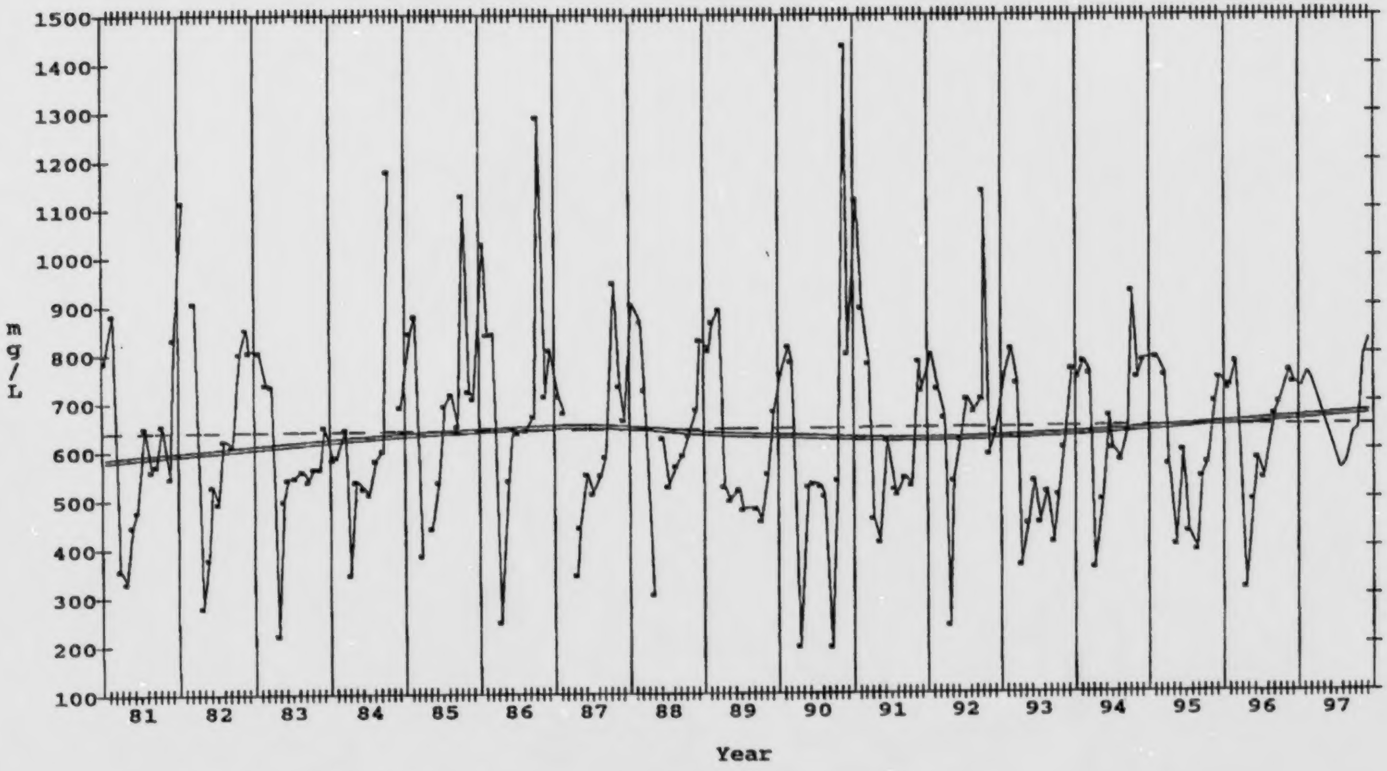
```
              HG-TOT    80011P    ( THE 6 YEARS MISSING DATA HAVE BEEN OMITTED )

      MONTH                    1        2        3        4        5        6        7        8        9       10       11       12

                            *        *        *        *        *        *                 *                          *        *
MANN & KENDALL STAT.        -2.9200  -2.8660  -2.6458  -2.7497  -2.2590  -3.1651  -1.8981  -2.2320  -1.4335  -1.6169  -2.7418  -2.7600
                            *        *        *        *                 *        *                                   *        *
SPEARMAN STAT.              -5.6912  -8.0024  -5.8847  -2.7433  -1.9149  -3.8187  -2.9086  -1.7421   -.8664  -1.6738  -2.3094  -5.2659

KENDALL COEFFICIENT          -.7273   -.8182   -.7435   -.4615   -.2821   -.6044   -.4872   -.3636   -.2051   -.3590   -.4103   -.6667

SPEARMAN COEFFICIENT         -.8741   -.9364   -.8909   -.6374   -.5000   -.7407   -.6593   -.4825   -.2527   -.4505   -.5714   -.8462

SEN LOWER CONF. INT.         -.0017   -.0017   -.0016   -.0025    .0000   -.0020   -.0012   -.0016   -.0012   -.0017   -.0025   -.0014

SEN ESTIMATED OF SLOPE       -.0011   -.0012   -.0009   -.0017    .0000   -.0012    .0000    .0000    .0000    .0000   -.0013   -.0007

SEN UPPER CONF. INT.          .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000    .0000

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =  -8.3802  *
 MODIFY SEA. KEN.  STATISTIC =  -3.0254  *
 VAN BELLE (HOMO)  STATISTIC =   3.3294
 VAN BELLE (TEND)  STATISTIC =  71.4819  *
 KENDALL         COEFFICIENT =    .1193
 SPEARMAN        COEFFICIENT =    .1587
 SEASONAL LOWER   CONF. INT. =   -.0011
 SEASONAL ESTIMATED OF SLOPE =    .0000
 SEASONAL UPPER   CONF. INT. =    .0000      * SIGNIFICANT AT 5 % LEVEL
```

```
              PB-TOT    82002P    ( THE 7 YEARS MISSING DATA HAVE BEEN OMITTED )

      MONTH                    1        2        3        4        5        6        7        8        9       10       11       12

                            *                 *        *        *        *        *        *        *        *        *        *
MANN & KENDALL STAT.        -2.3767  -1.3525  -2.7280  -2.5758  -3.1482  -3.1291  -3.4562  -2.3096  -3.5614  -3.6838  -3.4228  -2.4485
                            *                 *        *        *        *        *        *        *        *        *        *
SPEARMAN STAT.              -2.9406  -1.4924  -4.2691  -4.0775  -7.5895  -4.9291  -9.7317  -3.0169  -5.6912 -15.1941  -8.0057  -3.5667

KENDALL COEFFICIENT          -.5636   -.3778   -.7091   -.6061   -.7879   -.6923   -.8485   -.6000   -.7576   -.9394   -.8182   -.6364

SPEARMAN COEFFICIENT         -.7000   -.4667   -.8182   -.7902   -.9231   -.8297   -.9510   -.7091   -.8741   -.9790   -.9301   -.7483

SEN LOWER CONF. INT.         -.0006   -.0006   -.0006   -.0005   -.0005   -.0004   -.0005   -.0005   -.0005   -.0004   -.0005   -.0005

SEN ESTIMATED OF SLOPE       -.0003   -.0003   -.0004   -.0003   -.0003   -.0003   -.0003   -.0002   -.0003   -.0001   -.0002   -.0001

SEN UPPER CONF. INT.          .0000    .0001   -.0001    .0000    .0000   -.0001   -.0001    .0000   -.0001   -.0001   -.0001    .0000

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =  -9.9643  *
 MODIFY SEA. KEN.  STATISTIC =  -3.4650  *
 VAN BELLE (HOMO)  STATISTIC =   5.0455
 VAN BELLE (TEND)  STATISTIC =  97.3135  *
 KENDALL         COEFFICIENT =   -.1733
 SPEARMAN        COEFFICIENT =   -.2405
 SEASONAL LOWER   CONF. INT. =   -.0003
 SEASONAL ESTIMATED OF SLOPE =   -.0003
 SEASONAL UPPER   CONF. INT. =   -.0002      * SIGNIFICANT AT 5 % LEVEL
```

```
            245T    18510L  ( THE 1 YEAR MISSING DATA HAS BEEN OMITTED )

     MONTH                     1       2       3       4       5       6       7       8       9      10      11      12

                          *       *               *       *       *       *       *       *       *       *
MANN & KENDALL STAT.      3.0619  2.5981  1.6149  2.4840  3.4391  3.1455  2.6819  2.9394  2.8735  2.7240  3.0619  1.8858
                          *       *       *       *       *       *       *       *       *       *       *       *
SPEARMAN STAT.            5.5658  4.9929  3.7178  2.3524  6.8571  4.3995  2.7993  5.5658  4.0213  4.4580  5.5658  3.9744

KENDALL COEFFICIENT        .6571   .6381   .6381   .3524   .7124   .5833   .4265   .6571   .5033   .5735   .6571   .6264

SPEARMAN COEFFICIENT       .8393   .8107   .7179   .5464   .8638   .7618   .5858   .8393   .7090   .7549   .8393   .7538

SEN LOWER CONF. INT.       .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000   .0000

SEN ESTIMATED OF SLOPE     .0000   .0000   .0000   .0000   .0010   .0000   .0000   .0000   .0006   .0000   .0000   .0000

SEN UPPER CONF. INT.       .0044   .0000   .0000   .0048   .0044   .0048   .0044   .0042   .0040   .0037   .0044   .0034

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =    9.4022  *
 MODIFY SEA. KEN.  STATISTIC =    2.9939  *
 VAN BELLE (HOMO)  STATISTIC =    2.9915
 VAN BELLE (TEND)  STATISTIC =   88.0761  *
 KENDALL         COEFFICIENT =     .0320
 SPEARMAN        COEFFICIENT =     .0424
 SEASONAL LOWER   CONF. INT. =     .0000
 SEASONAL ESTIMATED OF SLOPE =     .0000
 SEASONAL UPPER   CONF. INT. =     .0007      * SIGNIFICANT AT 5 % LEVEL
```

```
            240     18500L  ( THE 1 YEAR MISSING DATA HAS BEEN OMITTED )

     MONTH                     1       2       3       4       5       6       7       8       9      10      11      12

                          *                                                                               *
MANN & KENDALL STAT.      2.8894   .7625  1.4896  -.1023  1.4808   .6897  -.2947  1.7884  1.7789  1.7520  2.4133   .6482
                          *                                                                               *
SPEARMAN STAT.            3.2353   .4675  1.2391  -.2842  1.7212   .7288  -.3527  1.2391  2.0444  1.9569  2.3966  1.0938

KENDALL COEFFICIENT        .4857   .1810   .2381  -.0095   .1895   .1333   .0000   .2190   .3464   .3088   .4667   .3187

SPEARMAN COEFFICIENT       .6679   .1286   .3250  -.0786   .3953   .1912  -.0907   .3250   .4551   .4510   .5536   .3011

SEN LOWER CONF. INT.       .0000  -.0023   .0000  -.0033   .0000  -.0063  -.0029   .0000   .0000   .0000   .0000   .0000

SEN ESTIMATED OF SLOPE     .0019   .0001   .0008   .0000   .0006   .0004   .0000   .0019   .0011   .0025   .0010   .0000

SEN UPPER CONF. INT.       .0028   .0021   .0029   .0036   .0024   .0033   .0029   .0049   .0031   .0123   .0037   .0020

 OVER ALL RESULTS

 SEASONAL KENDALL  STATISTIC =    4.3684  *
 MODIFY SEA. KEN.  STATISTIC =    2.6135  *
 VAN BELLE (HOMO)  STATISTIC =   10.0944
 VAN BELLE (TEND)  STATISTIC =   19.4969  *
 KENDALL         COEFFICIENT =     .0324
 SPEARMAN        COEFFICIENT =     .0645
 SEASONAL LOWER   CONF. INT. =     .0000
 SEASONAL ESTIMATED OF SLOPE =     .0007
 SEASONAL UPPER   CONF. INT. =     .0016      * SIGNIFICANT AT 5 % LEVEL
```

AS99 -- TDS*



- - is the least squares best fit line: 2.196849e-03*X -949.932438
Sig. of slope = 0.780386; R = 0.020199
= is the LOWESS smoothed curve; smoothing factor 0.5

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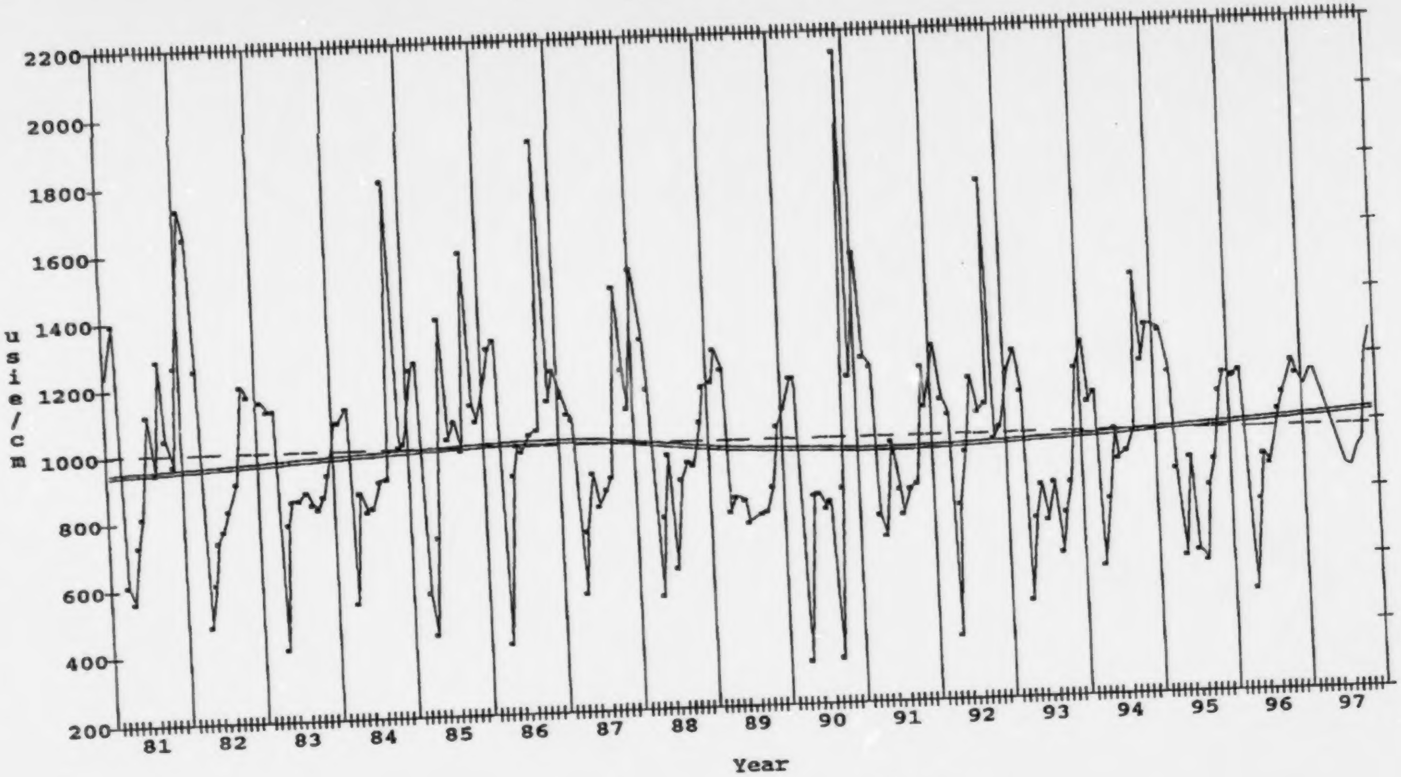
AS99CON

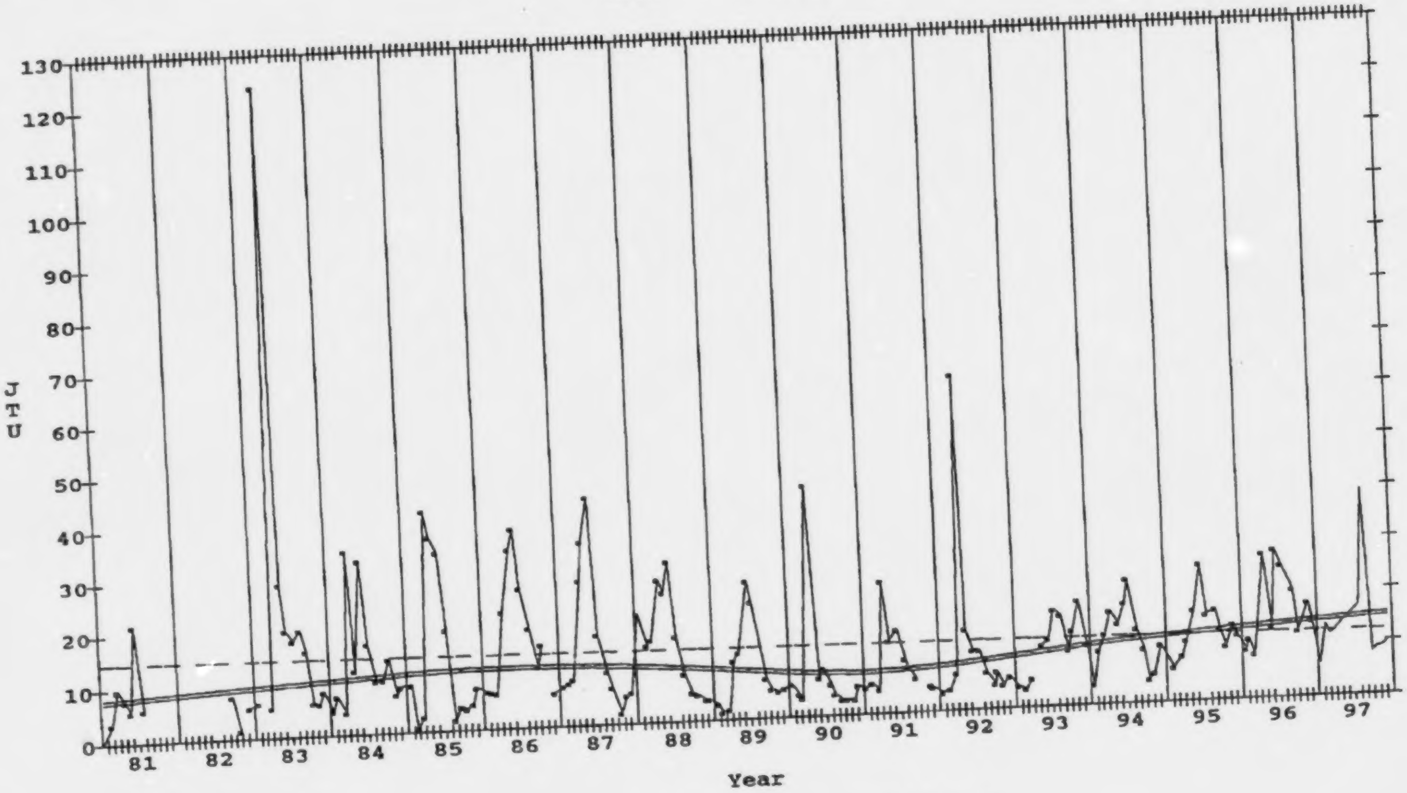
AS99 -- Cond(F)



- - is the least squares best fit line: -2.760395e-03*X +3000.301904
Sig. of slope = 0.810593; R = 0.017183
= is the LOWESS smoothed curve; smoothing factor 0.5

AS99TURB

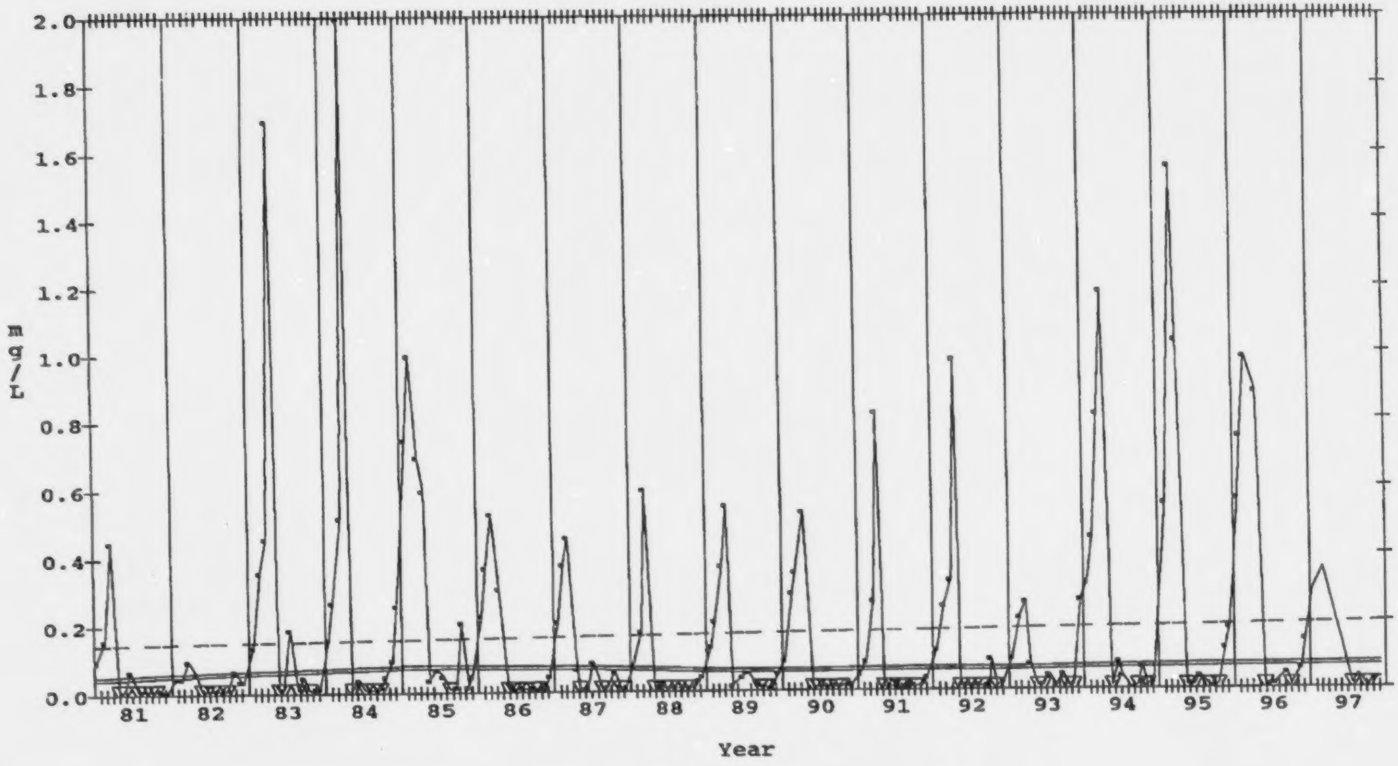
AS99 -- Turb.(F)



- - is the least squares best fit line: -4.019359e-04*X +305.279365
Sig. of slope = 0.48896; R = 0.051903
= is the LOWESS smoothed curve; smoothing factor 0.5

AS99N 07-JAN-99 8:31 Page 1

AS99 -- NO3+NO2



- - is the least squares best fit line: 8.869443e-06*X -6.271774
Sig. of slope = 0.475095; R = 0.051047
= is the LOWESS smoothed curve; smoothing factor 0.5

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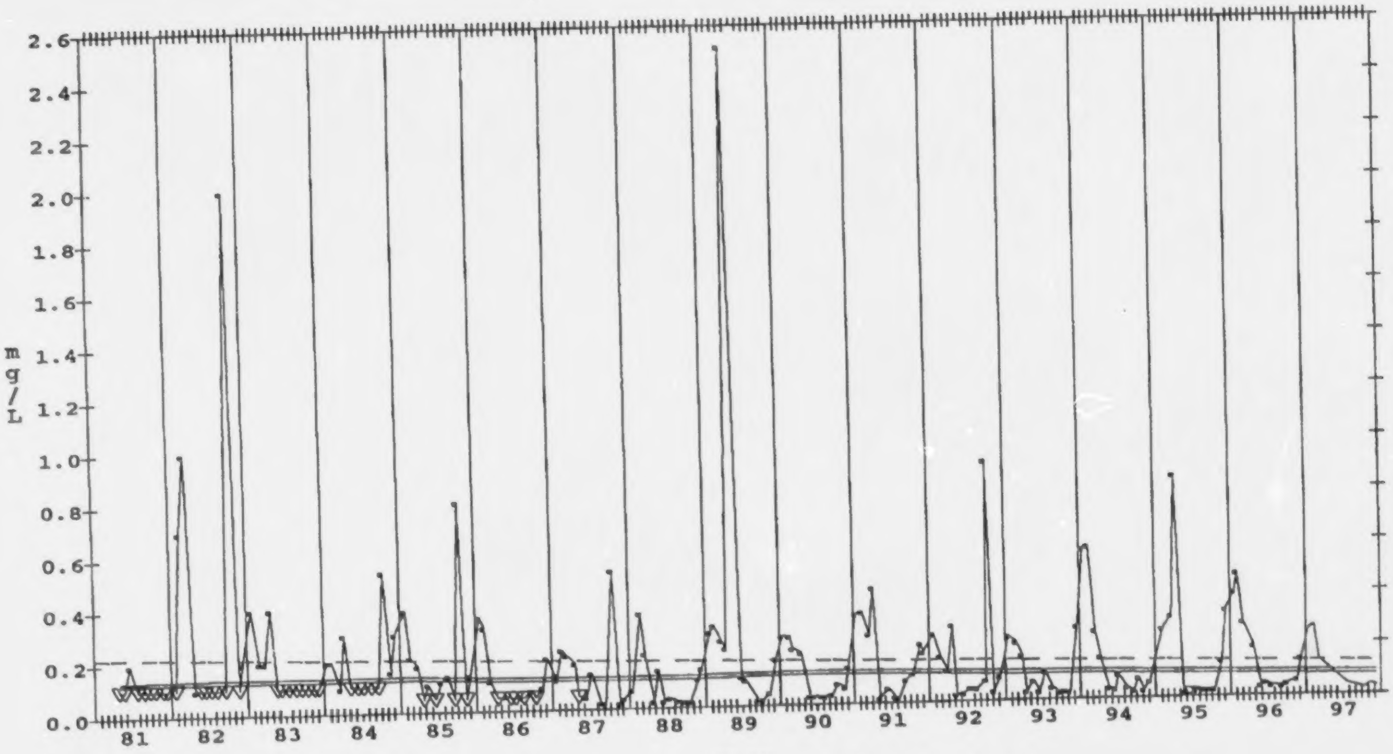
AS99NH

AS99 -- NH3-tot



- - is the least squares best fit line: -1.533592e-05*X +11.313375
Sig. of slope = 0.168509; R = 0.099004
= is the LOWESS smoothed curve; smoothing factor 0.5

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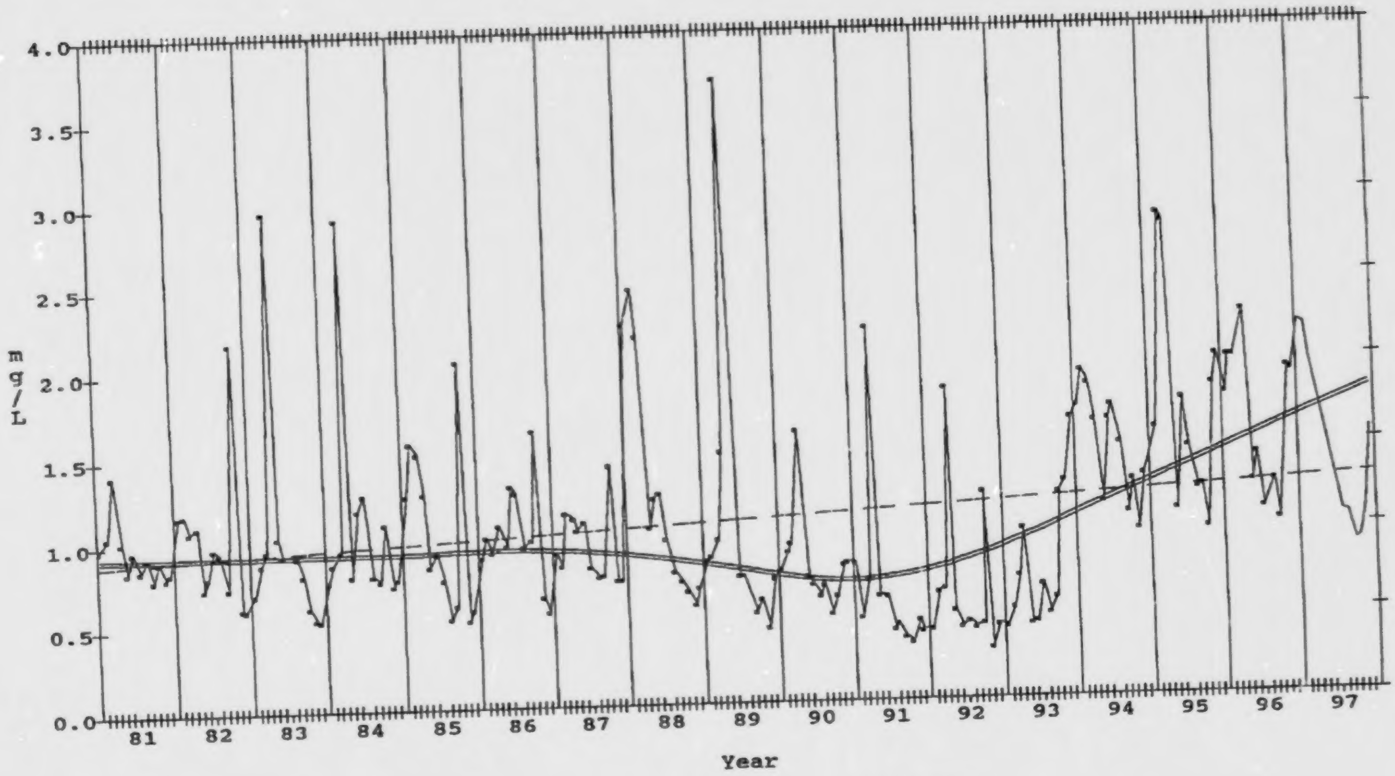
AS99TN

AS99 -- TN*



- - is the least squares best fit line: 6.744598e-05*X -47.896081
Sig. of slope = 0.003186; R = 0.209123
= is the LOWESS smoothed curve; smoothing factor 0.5

AS99PH

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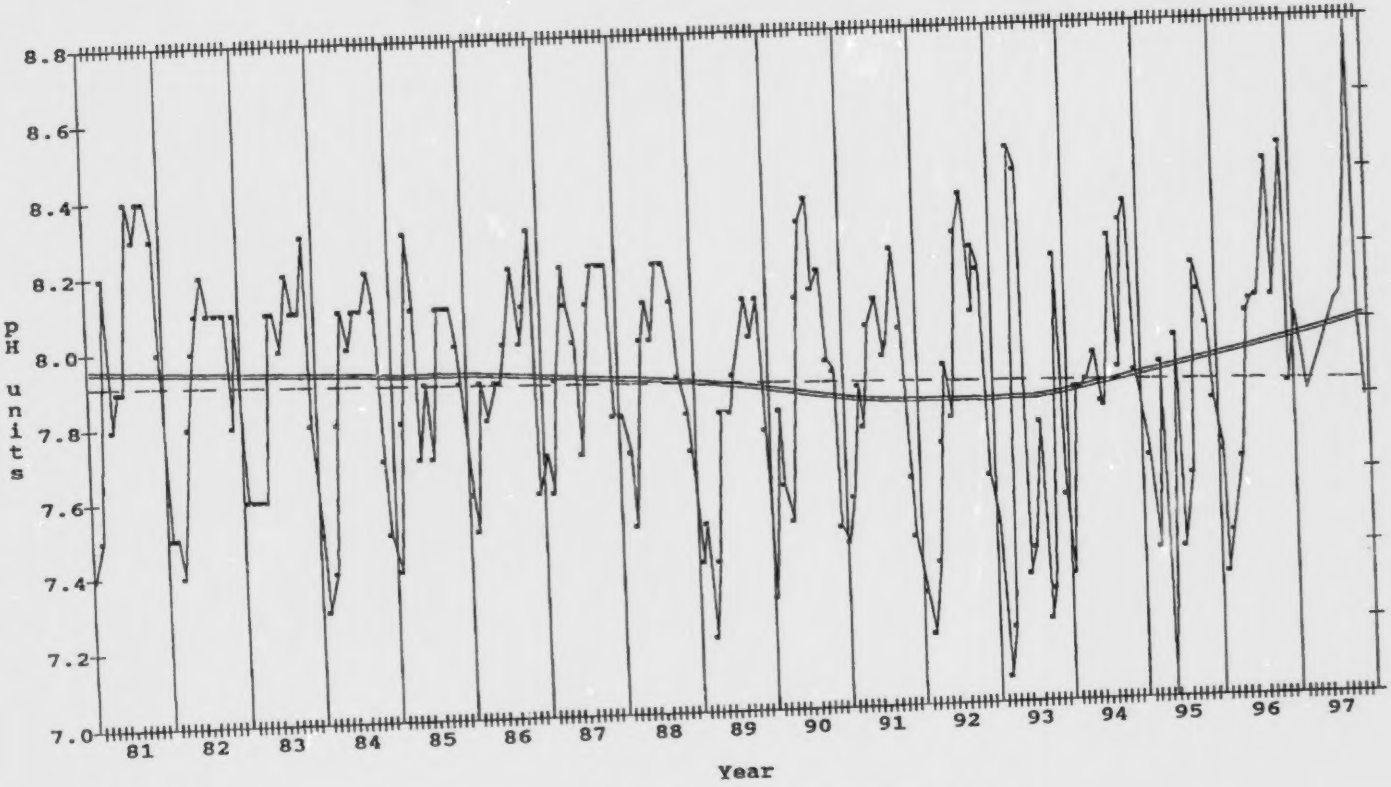
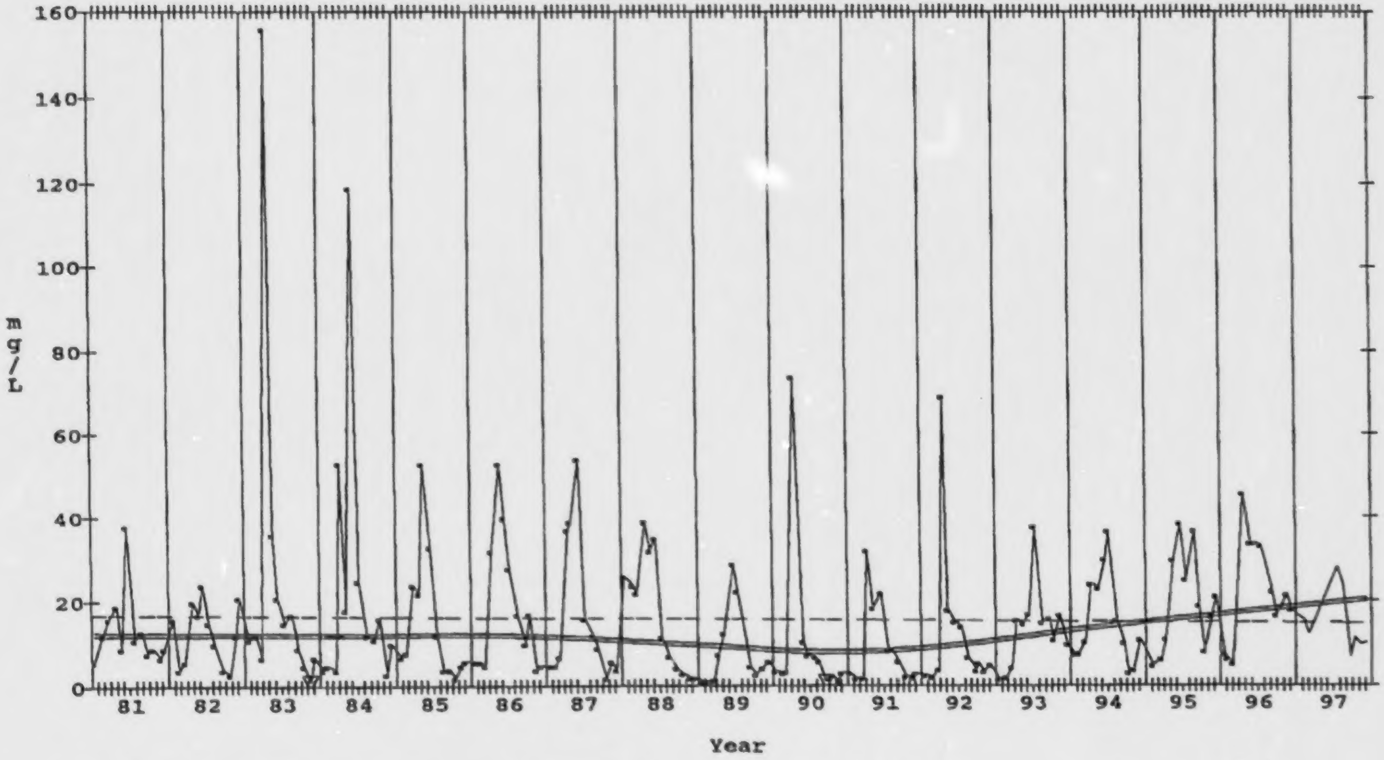
AS99 -- pH(F)



- - is the least squares best fit line: -1.158686e-05*X +16.289776
Sig. of slope = 0.373938; R = 0.063525
= is the LOWESS smoothed curve; smoothing factor 0.5

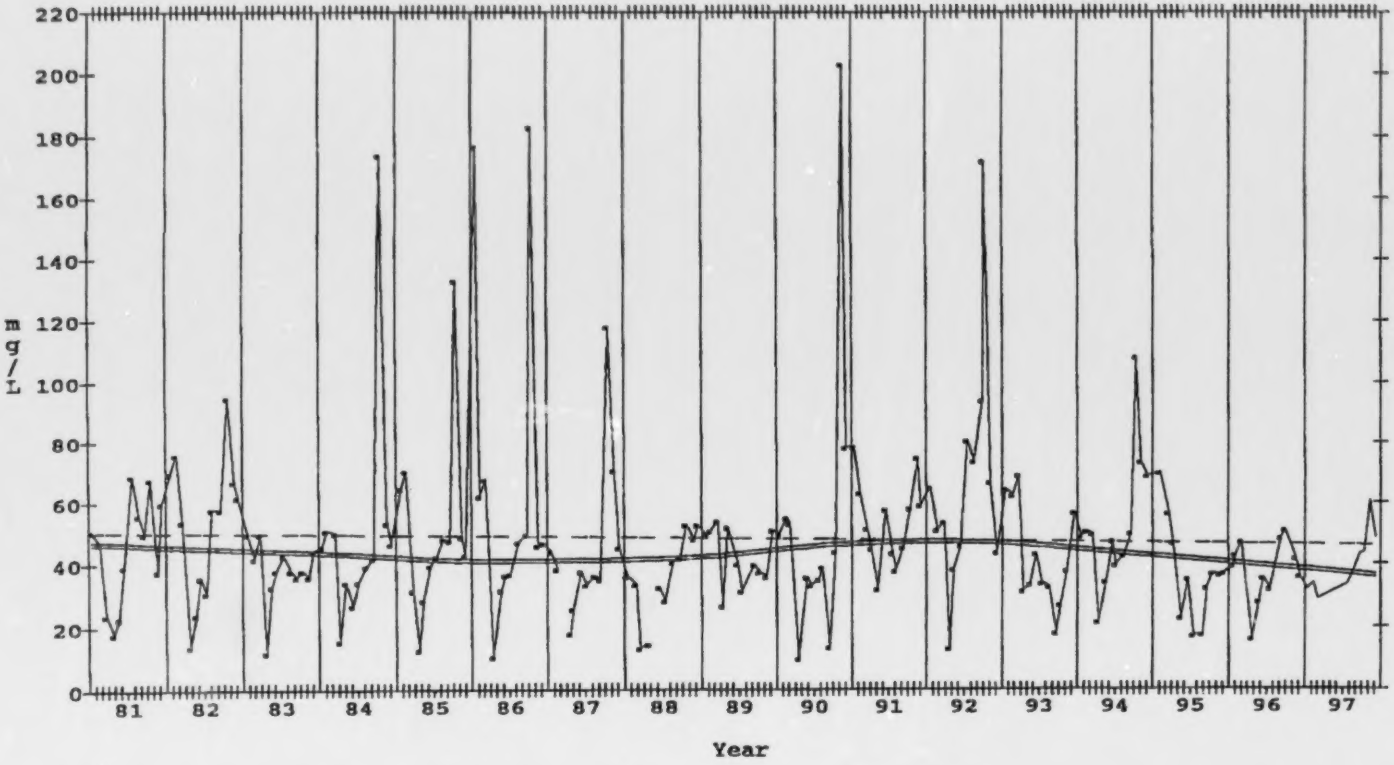
AS99 -- NFR



- - is the least squares best fit line: -3.578358e-04*X +275.577431
Sig. of slope = 0.62399; R = 0.035048
= is the LOWESS smoothed curve; smoothing factor 0.5

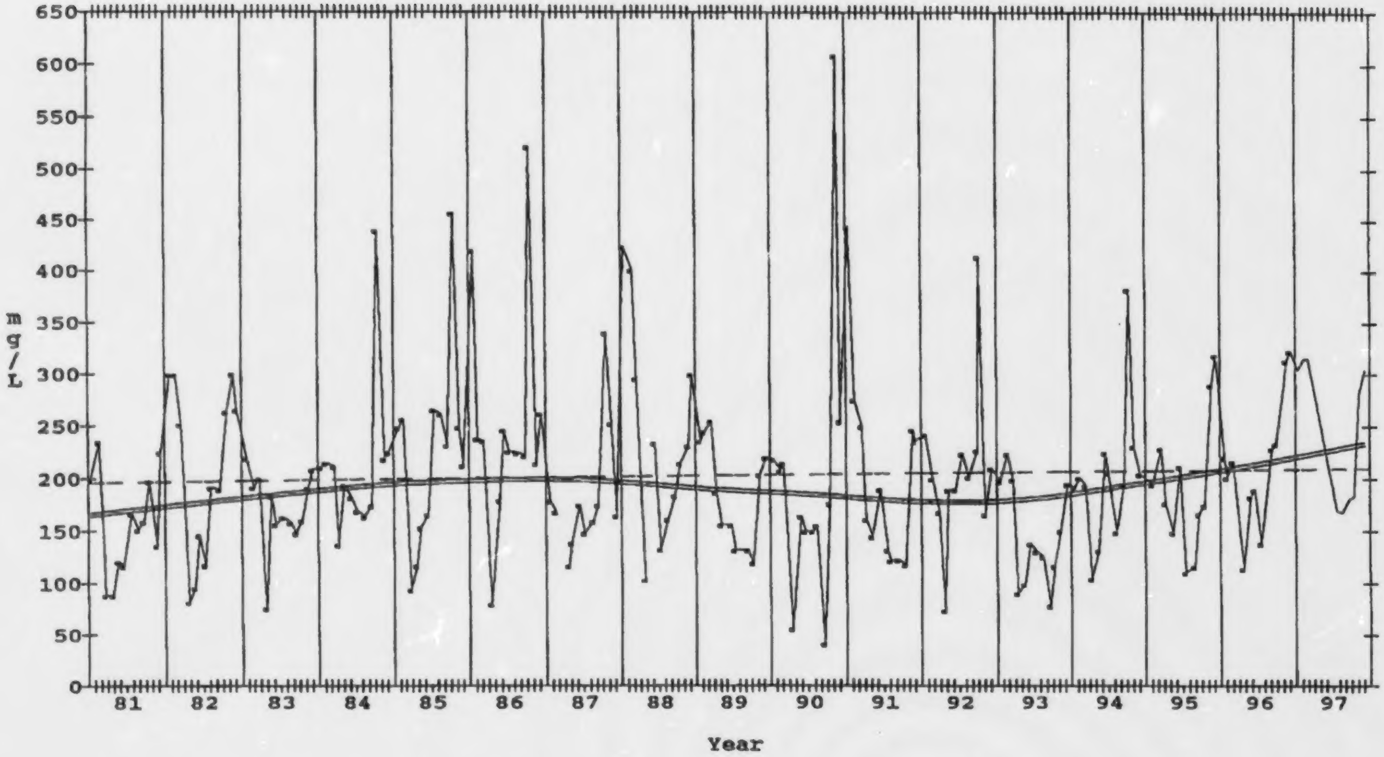
AS99NA 06-JAN-99 16:25 Page 1

AS99 -- Na-diss



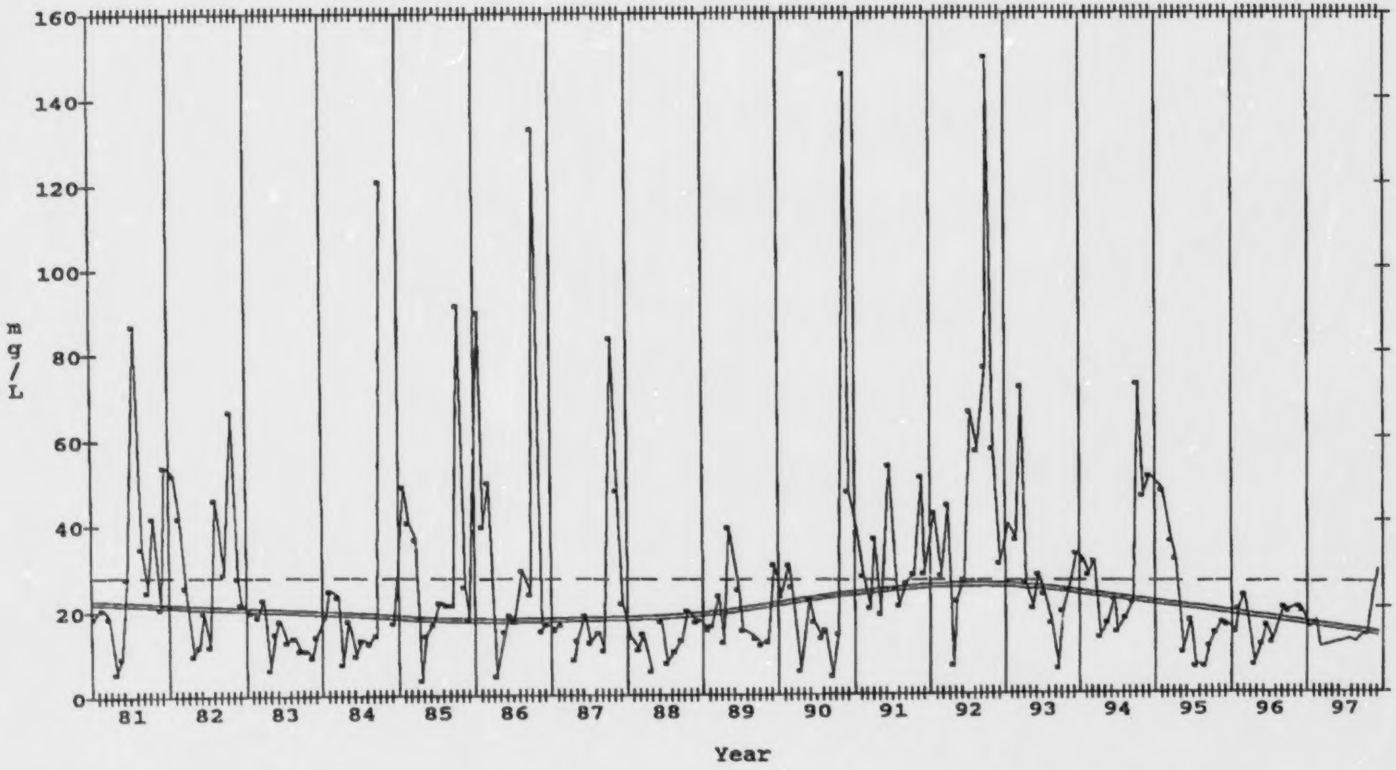
- - is the least squares best fit line: -6.892404e-04*X +548.858163
Sig. of slope = 0.548492; R = 0.043115
= is the LOWESS smoothed curve; smoothing factor 0.5

AS99 -- SO4-diss



- - is the least squares best fit line: 2.291267e-03*X -1461.065822
Sig. of slope = 0.493965; R = 0.049143
= is the LOWESS smoothed curve; smoothing factor 0.5

AS99 -- Cl-diss

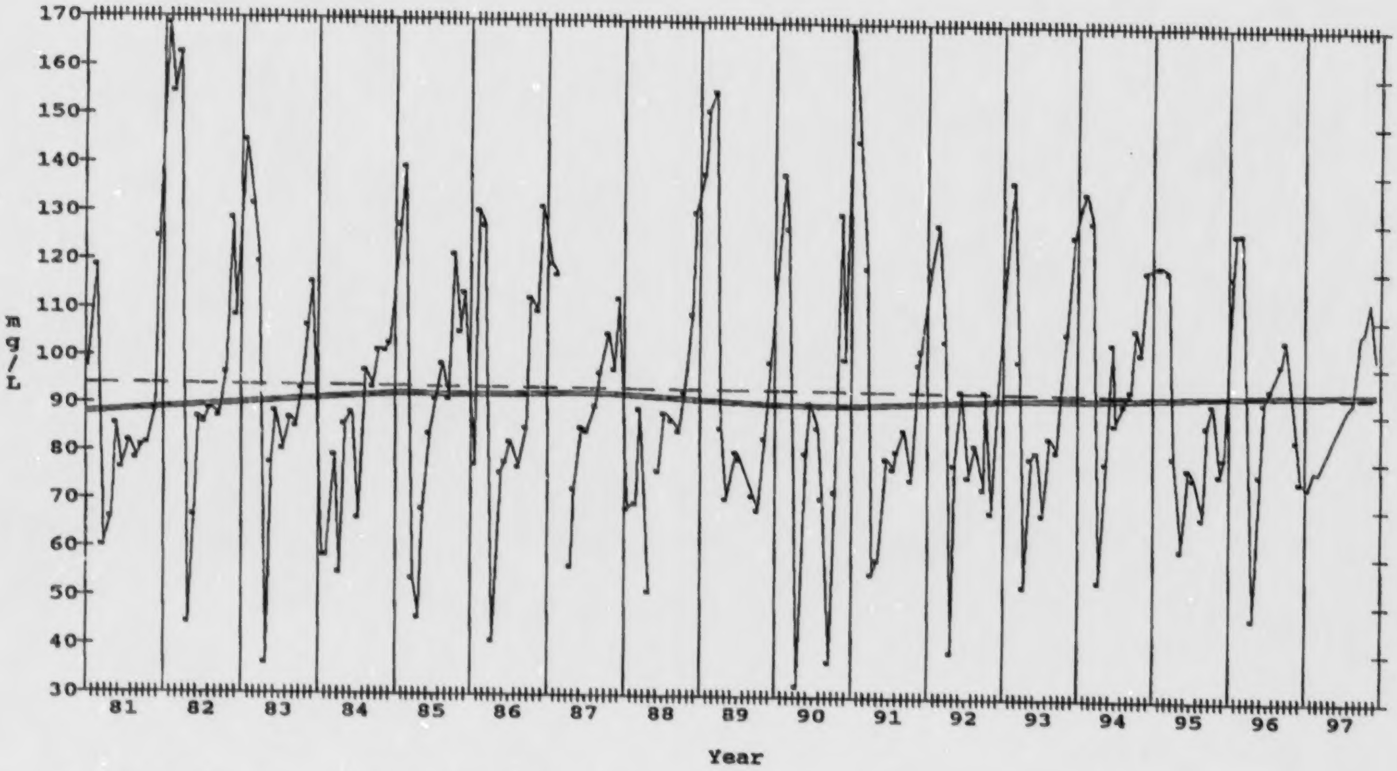


- - is the least squares best fit line: -3.451394e-04*X +277.594512
Sig. of slope = 0.713501; R = 0.026458
= is the LOWESS smoothed curve; smoothing factor 0.5

AS99CA

06-JAN-99 16:29 Page 1

AS99 -- Ca-diss



- - is the least squares best fit line: -9.047156e-05*X +159.590734
Sig. of slope = 0.932115; R = 0.006124
= is the LOWESS smoothed curve; smoothing factor 0.5

AS99ZN

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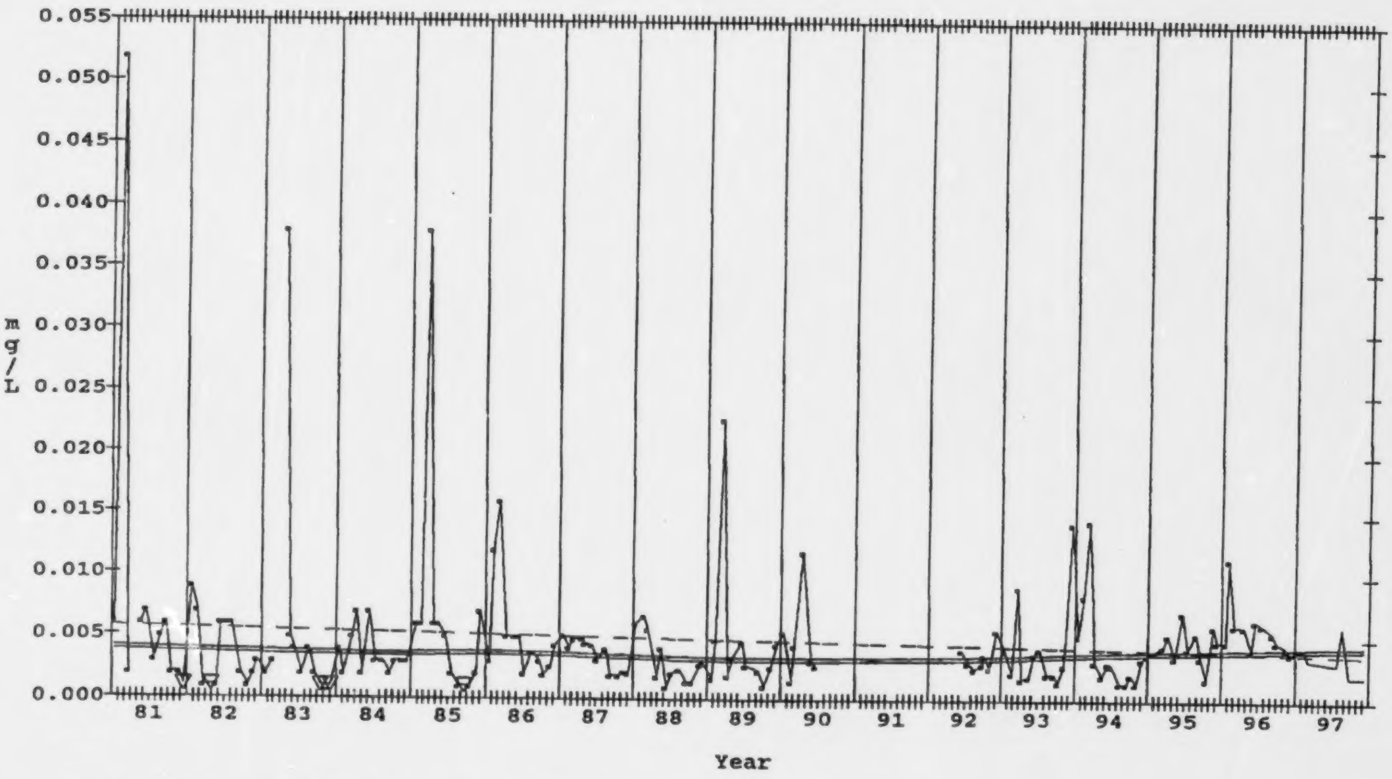
AS99 -- Zn-tot



- - is the least squares best fit line: -3.292762e-07*X +0.243816
Sig. of slope = 0.177139; R = 0.103083
= is the LOWESS smoothed curve; smoothing factor 0.5

APPENDIX 4
DEFINITIONS OF STATISTICAL TERMS

A Statistic: A quantity computed from a set of observations. Mean, median, and variance are examples of statistics.

Auto-Dependence: Same meaning as serial dependence.

Bias: An estimate of a quantity (parameter) is unbiased if the mean of the estimates obtained from all possible samples which are generated from the assumed population is identical with the parameter we want to estimate.

Censored Data: A data point is censored if its value is known to be larger or smaller than a specific value which is known prior to the data collection. This is called type I censoring which occurs frequently in water quality studies. An example of this type of censoring is a value below the detection limit of the measuring instrument.

Extreme Values: A value is extreme when the probability of its occurrence is extremely small. This probability is measured on the basis of distributional assumptions. For example, when observation is considered to be an extreme under the assumption of a normal distribution, it may not be an extreme when another distribution is assumed.

Missing Data: A data point is missing when its value is not available. This may be due to logistical or analytical reasons. Missing values may or may not be ignored in the statistical analysis of the data.

Natural Flow: Means the quantity of water which would naturally flow in any watercourse had the flow not been affected by human interference or human intervention, excluding any water which is part of the natural flow in Alberta but is not available for the use of Alberta because of the provisions of any international treaty which is binding in Alberta.

Parametric Methods: Methods in which the observations or error terms in a model constitute a random sample from a probability distribution that can be represented by some functional form involving a parameter, such as the normal or Poisson distributions. For non-parametric methods it assumed only that the observations constitute a random sample from some population.

Power Of The Test: The probability of correctly rejecting H_0 when the alternative hypothesis H^ is true. In testing for trend, H_0 is the hypothesis of no trend and H^, for example, could be the hypothesis of a monotonic (increasing or decreasing) trend.

Regression Methods: Statistical tools commonly used to build empirical models. The objectives of such models are to isolate, estimate and make inferences about systematic and random variations observed in the data.

Robust Methods: Methods which are not sensitive to deviations from the assumptions upon which the statistical analysis is based.

Seasonal Variation: A regular and systematic variation that occurs within a year (usually cyclic). This could be attributed directly or indirectly to yearly climatic cycle.

Serial Dependence: Serial dependence may occur when the values are made sequential in time. This means that a value measured at a time point provides information on another observation made at another point in time.

Serial or Auto-Correlation Coefficient: A measure of serial dependence and is usually used as a tool for building and checking the adequacy of time series models.

Significance Level: The probability of incorrectly rejecting the null hypothesis, H_0, when it is true.

Time Series: A sequence of values (observations or measurements) collected at equal or unequal time intervals over a period of time. For data collected within the year, e.g. weekly, monthly or quarterly, the observed variation in the series can be decomposed into systematic (seasonal and trend) and random (variation without systematic pattern).

Trend: A systematic variation that occurs over a time period longer than a year. There are several forms for the trend (a) monotonic (consistently increasing or decreasing); (b) non-monotonic such as step trend or cyclic trend.

Appendix IV

Saskatchewan's
Pesticide Container Management Program

as set out by the
Pesticide Container Management Advisory Board

Saskatchewan's Pesticide Container Management Program

1. Siting Criteria

The following is a list of guidelines to be considered for establishing or setting up a pesticide container collection site in Saskatchewan.

A. Location and Topography

- A flat to gently undulating area which drains to adjacent croplands or buffer strips is recommended.
- High ground is recommended and runoff waters originating from the container collection site must NOT be permitted to enter surface water supplies, dugouts, streams, creeks, lakes or other water bodies.
- Wet or flood prone areas must be avoided.
- In the event that the site is to be located in association with an existing municipal waste disposal grounds, it should be situated between the entrance and the current disposal area.

B. Isolation Distances

- The container collection site should not be located within 500 metres of a residence.
- The container collection site should not be located within 500 metres of a watercourse.
- A container collection site located in conjunction with a supervised waste disposal ground should be situated at a lower grade and at least 50 metres downwind, in the direction of the prevailing winds, from shelters or work place.

C. Soil and Subsoil Characteristics

- Soils containing higher proportions of clay and silt are preferred for container collection sites.
- Soils containing a higher proportion of sand and course textured soil containing more than 75% sand (i.e. sand, loamy sands and sandy loans) should be avoided.
- Known or suspected groundwater recharge areas must be avoided.

D. Physical Requirements

- Access - The site should be close to a main access road. The area between the main access road and the site itself should be fairly level to provide reasonable access by farmers and the contractor performing the container processing and hauling.

- Fencing and Separation of Containers - The site should be fenced on all four sides and a gate wide enough to accommodate access by a semi-trailer (12 feet) should be provided. The site should be segregated into fenced and placarded areas for separate metal and plastic container storage.

- Site Area - The area required for a particular site is dependant upon the number of pesticide containers which can be expected to be generated with the rural municipality. The size of the container collection site will therefore vary, however, the minimum recommended area is 2,000 feet which would allow for access by the contract responsible for the annual crushing and removal of containers.

E. Public Consultations

In order to facilitate the efficient operation of a container collection site, it will be of great benefit to inform the public in your municipality what you are trying to accomplish with your collection site. This will not only provide the ratepayers an opportunity to participate in the site selection process, it will also make them aware of their responsibility in the process of container collection or recycling. The farmers are responsible for the proper rinsing of the empty containers and for the delivery of the rinsed containers to a designated collection site in the area.

F. Approval

A written approval from Saskatchewan Environment and Resource Management must be obtained prior to proceeding with any container collection site construction or establishment works.

2. Site Operational Guidelines

- as set out by the Pesticide Container Management Advisory Board

A. Site Size

Each site shall be fenced with chain link, concrete mesh, page wire or game wire with a minimum height of 4 feet, containing a minimum of 2,000 square feet. If this type of fence is already in place, the 2,000 square foot minimum does not apply until such time as the fence needs to be replaced. The fence shall have a secure gate wide enough to accommodate access by a semi-trailer unit - minimum of 12 feet.

B. Separation of Containers

Each site shall be set up in such a manner as to contain two areas, one for empty metal containers and one for empty plastic containers. These areas shall be identified by signs.

C. Proper Signage

Each site shall have proper signage as follows:

- at the entrance to the site a sign indicating that:
  - i) it is a pesticide container collection site
  - ii) triple rinsed metal containers are to be stacked on their sides
  - iii) only empty containers allowed
  - iv) absolutely no burning allowed
- at each of the two areas a sign indicating either:
  - i) stack empty metal containers here, or
  - ii) place empty plastic containers here (remove from cardboard boxes)

D. Handling of Bags for Dry Granular Agricultural Chemicals

Site patrons should be advised that bags from dry granular chemicals should be precleaned with a water hose before disposal to remove any residual product. Cleaning should be performed in an area where the residual material will not result in the contamination of surface or groundwater. Once cleaned, these bags may then be placed in the municipal landfill.

E. Appearance & Maintenance

Absolutely no other garbage, cardboard boxes, paper, industrial chemical containers, etc. allowed within the perimeter of the collection site. It must be neat and tidy in appearance at all times.

Cardboard boxes shall be delivered to the nearest waste disposal ground. Metal containers shall be stacked on their sides at all times so as to prevent the entry of precipitation.

F. Absolutely No Burning Allowed

Regular maintenance should be arranged to monitor and repair site conditions such as signs, fence, gates and general appearance.

Appendix V

Public Information

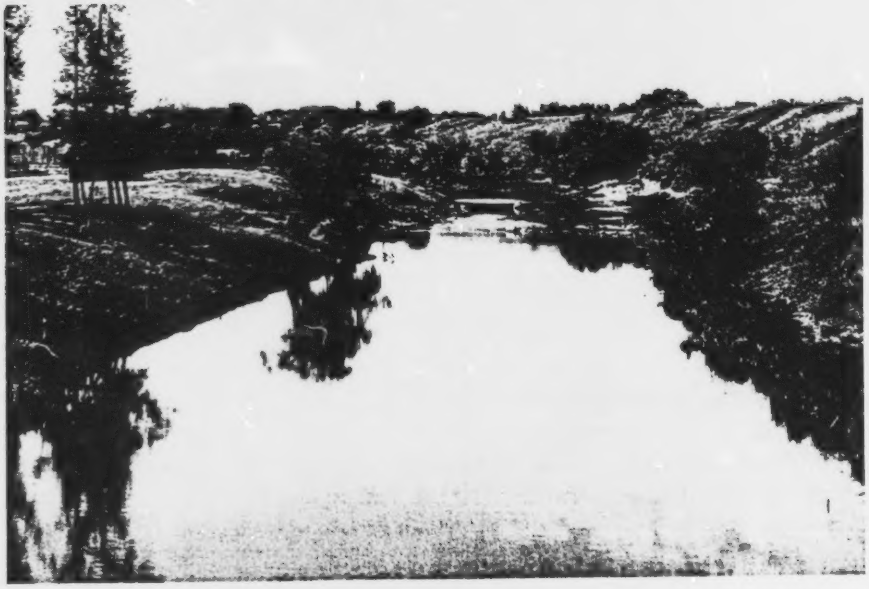
Kopelchuk Project: Off-Stream Cattle Watering Demonstration Site

Town of Roblin: Alternate Effluent Management

Water Quality in the Upper Assiniboine River Basin

Kopelchuk Project

Off-Stream
Cattle Watering
Demonstration
Site



V.1

Cattle producers appreciate the value of a reliable supply of good quality water. It is essential in producing healthy and efficient animals.

Recent research has shown that clean drinking water also benefits livestock performance. Given a choice, studies have shown that cattle prefer to drink from a trough rather than from a surface water supply like a creek, dugout, river or slough. The daily rate of weight gain can be significantly greater for the cattle using a trough as compared to those accessing surface water directly.

Cattle producers are aware of public concern about maintaining a safe water supply. The cattle may not necessarily be the major contributor to stream bank deterioration at a given site. However, cattle producers understand that they have an impact on the stream as a direct result of the management system they practice.

Herd and range management practices are now focusing on techniques that protect or enhance water quality by restricting livestock access to surface water supplies. These techniques tend to encourage vegetative growth in riparian areas. An increase in the numbers of woody plants improves stream bank stability and eventually offers better shelter for the cattle. The increased plant growth and stability of the stream bank leads to healthier and more diverse aquatic life in the stream or river.

Demonstration Site near Canora

Horned Hereford cattle have been a familiar site for the past 50 years on the Kopelchuk farm (PK Herefords), located south of Canora on Hwy. No. 9 along the Whitesand River. The Kopelchuks approached Saskatchewan Agriculture and Food in the spring of 1998 to discuss alternatives to the pasturing and over-wintering system they were practicing. The Kopelchuks graze 60 cow/calf pairs on 65 hectares (160 acres) of native and tame pasture. The Whitesand River flows north through the east side of the quarter section. From the west, the Good Spirit Lake drainage channel dissects the quarter section and joins the Whitesand River.

The Kopelchuks wanted to move the wintering site from the river's edge to an upland area north and west of the main yard. The Upper Assiniboine River Basin Study Water Quality Committee became involved and supported their plans. The Study group also suggested an off-stream watering system trial during the summer of 1998 to determine the practicality of fencing along the banks of the Whitesand River. With support from the District #19 ADD Board (Agriculture, Development and Diversification), the Kopelchuks agreed and the project was initiated.

The Off-Site Watering System

A solar powered 24 volt pumping unit was installed to deliver water from the Whitesand River to a trough on the edge of the river bank. Two 12 volt marine batteries powered both the pump and electric fence. About 2.5 km (1.6 miles) of electric fence was installed along both sides of the river to restrict the cattle from watering in the river. A river crossing for the cattle was established by placing gates in the electric fence on either side of the river at one location.

Observations

It took two days to place the electric fence along both sides of the Whitesand River. The fence was energized and marked with ribbon as each section was completed. By the time the fence was completed, the cattle had been trained and were remaining out of the area between the fence and the river. The fence was in place and working before the solar pumping system was installed. The cattle had access to the river only at the established crossing.

Conclusions

Fencing of a water course is not always the practical answer to riparian area protection. In the Kopelchuk pasture, the Whitesand River is relatively wide and shallow. It is prone to flooding in the spring and has variable water depth throughout the summer and fall due to rainfall and up-stream water management. A heavy rain in June 1998 raised the water level of the river sufficiently to flood sections of the electric fence. Although the fence withstood the onslaught of water and debris very well with only minor repairs necessary, it demonstrated that such an approach was not a long term solution. In October 1998, the fence and watering system were removed.

On a river with such a wide and low flood plain, a rotational grazing system may be the solution. Cattle can be allowed to graze for a short time and then move to another pasture. This type of system works well for grazing in the fall when water levels are usually at their lowest and forage supplies elsewhere in the pastures are declining.

Current Activities

The solar powered pump and watering system were re-installed in the Kopelchuk pasture in May 1999. The river was not fenced. The cattle had a free choice to water from either the river or a trough. A water meter was placed in the delivery line to the trough to measure total water pumped to the trough over the summer months.

Research has shown that cattle prefer to water from a clean trough rather than a static water source which they must enter to drink (i.e. a dugout or slough). The demonstration is intended to show whether cattle exhibit this preference with flowing water as well. Flowing water tends to experience less quality degradation over the summer months than standing water.
The cattle's over-wintering site at the edge of the river was relocated during the summer and fall of 1999. For the 1999/2000 winter confinement period, PK Herefords will be operating in new facilities north and west of the present yard site.

This project was made possible through the involvement of many agencies and in particular the Kopelchuk families. The Upper Assiniboine River Basin Study, a joint initiative of Manitoba, Saskatchewan and Canada, wishes to acknowledge the following for their technical input and commitment of time to ensure the demonstration would proceed:

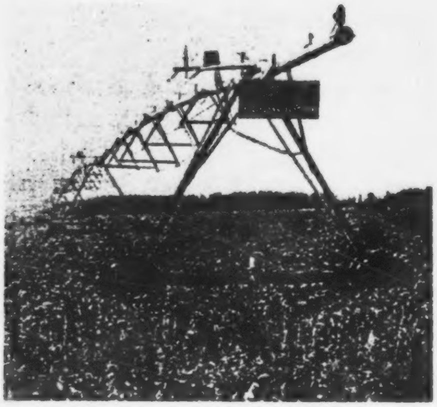
PK Herefords
UARBS, Water Quality Committee
Ducks Unlimited
District #19 ADD Board
Sask. Environment and Resource Management
Sask Power

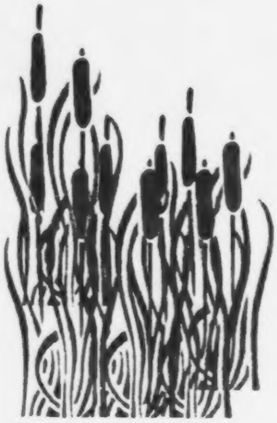
For more information contact:
Sask. Agriculture & Food
Yorkton
(306) 786-1550
or
PFRA
Melville
(306) 728-6651

Town of Roblin

Alternate Effluent Management

Effluent Irrigation ➢





➢ Engineered Wetlands

Hybrid Poplar Plantation ➢

The Town of Roblin, like most communities that dot the prairie landscape, relies on lagoons as part of its effluent treatment process. A standard lagoon system is comprised of a primary cell and one or more secondary cells which provide the proper conditions to allow nature to treat the sewage before discharge.

Sewage from Roblin enters the primary cell where heavy organic matter settles out while the lighter organic matter remains suspended. With assistance from the sun and wind, aerobic, anaerobic and facultative bacteria break down this organic matter and purify the effluent. As the effluent quality improves, the cleaner liquid is transferred into the secondary cells where the purification process continues. Once the effluent reaches a quality sufficient to meet environmental requirements for disposal, the secondary cells are discharged.

For dilution purposes and for continued natural purification, the effluent is usually discharged into a local stream or river during times of high water flow.

By contrast, since 1979, the Town of Roblin has used all of the liquid processed through its lagoon system to irrigate cropland adjacent to the lagoons.

With the wetter weather conditions encountered in the 1990s, too much liquid was being produced to be disposed of properly through the irrigation system.

The Town investigated a number of other potential disposal methods that could be incorporated into its overall effluent management scheme. As a result of this investigation, a 16 hectare (40 acres) wetland was constructed and a 6 to 8 hectare (15 to 20 acres) hybrid poplar plantation was created next to the lagoon area for post secondary treatment of a portion of the effluent.

Wetlands

A constructed wetland is a marsh that has been designed, built and operated for a particular purpose, often at a site that was not previously a wetland.

Constructed wetlands are normally seeded with a variety of reed, sedge, rush and other marsh grass plants. In order to properly optimize plant growth and longevity, the liquid levels within the cells are maintained at an optimum level of 30 cm (12 in.). As the liquid passes through the various cells, the natural purification process continues as bacteria further break down the organic matter. In addition, the floating and rooted plants remove much of the nutrients such as nitrogen and phosphorus from the liquid, further improving the water quality.

The following chart indicates the average nutrient reduction achieved in wetlands of this nature.

Parameter	In (mg/l)	Out (mg/l)	Removal Efficiency (%)
BOD_5	38.8	10.5	73
TSS	49.1	15.3	69
NH_3-N	7.5	4.2	44
TN	14.0	5.0	64
TP	4.2	1.9	55

BOD_5 = Five day Biochemical Oxygen Demand
TSS = Total Suspended Solids
NH_3-N = Ammonia Nitrogen
TN = Total Nitrogen
TP = Total Phosphorous

Due to the shallow nature of the wetlands, the area covered and the large mass of plants, much of the liquid is lost to evaporation and evapotranspiration. It is anticipated that no discharges from the wetlands will be required in all but wet years.

Hybrid Poplar Plantation

Hybrid poplar trees, planted around the lagoons, wetland cells and other adjacent areas, will not only provide seepage control but will also provide an additional use for the effluent.

Since these trees grow quickly and require a great deal of moisture for growth, large amounts of effluent can be used for irrigating the trees. Once they are established, their liquid requirements will increase due to the amount of evapotranspiration from the trees.

Other Ongoing Projects

In order to reduce the amount of effluent being produced, the Town is implementing a water conservation plan and is looking at a number of other options, including the control of groundwater infiltration into the sewage system.

Overview

The inclusion of a wetlands and hybrid poplar plantation to the existing irrigation system, along with future actions to reduce effluent production, will have many positive benefits. These innovations will improve the Town's ability to properly dispose of the effluent, and will limit the amount of nutrients being discharged into the Shell River which eventually flows into Lake of the Prairies. This will assist in maintaining the water quality in the lake for local people, fish, wildlife and recreation.

The amount of effluent disposed of through the irrigation system will be reduced. This will enable better management of crop irrigation, maximizing crop production while reducing possible damage to the soil.

The constructed wetlands and hybrid poplar plantation will provide an excellent habitat for wildlife and birds. The local school has already expressed interest in using the area for outdoor education.

With progressive thinking and ingenuity, other communities can realize a number of benefits and at the same time reduce the impact on water bodies by reducing or eliminating surface water discharges from their lagoons.

This brochure has been produced by the Town of Roblin and the Upper Assiniboine River Basin Study, a joint initiative of Manitoba, Saskatchewan and Canada.

This study is designed to assess the Basin's water resources and the impact of current and future development activity.

For more information about the Roblin alternative effluent management program, please call the Town of Roblin (204) 937-8333.

Water Quality in the Upper Assiniboine River Basin

Water Quality in the Basin
Water Quality Trends
Drainage and Water Quality
Livestock and Water Quality
Groundwater Protection
Municipal Lagoons

Upper Assiniboine River Basin Study

The Upper Assiniboine River Basin Study is an initiative of the governments of Saskatchewan, Manitoba and Canada. The study is designed to assess the Basin's water resources and the impact of current and future development activity.

Some of the important issues include drainage of agricultural lands, flooding, interprovincial water management, water supply, water quality and loss of wetlands.

The study area (see map on inside back cover) encompasses 21,000 square kilometres, with 79 per cent located in Saskatchewan. Approximately 60,000 people live in the Basin, which includes the communities of Yorkton, Langenberg, Melville, Canora, Kamsack and Preeceville in Saskatchewan and Roblin and Russell in Manitoba.

Drainage and Water Quality

Movement of water across cultivated fields affects water quality in the Upper Assiniboine River Basin. Of the 21,000 sq. km (8,000 sq. mi.) of land in the basin, 57 per cent is cultivated.

Surface and groundwater quality can be affected by the following:

- The addition of nitrogen or phosphorus can cause toxic algae blooms and excessive weed growth. Chemical fertilizers and manure are sources of nutrients that can enter surface or groundwater directly or with runoff.
  - Nutrient surpluses in the soil result when fertilizer application rates exceed crop uptake rates. Analysis of manure prior to spreading and fertilizing according to soil test recommendations can minimize these excesses and limit nutrient runoff from agricultural land.
  - Nitrogen is found in high concentrations in nature. However, some forms of nitrogen which result from fertilizer or manure runoff can be toxic to aquatic life. High concentrations of nitrogen and phosphorus can promote eutrophication resulting in excessive algae and aquatic weed growth.
- Contamination of water by pesticides used to control weeds, insects and fungi is a potential concern on the Prairies. Some areas within the Upper Assiniboine River Basin are susceptible to contamination due to soil type, slope, climate and depth to groundwater.
- Erosion and sedimentation can impact water quality in the Basin. Excessive tillage, cultivation of marginal lands and construction of drains can lead to erosion under the right runoff, soil type, and slope conditions. Erosion results in the loss of valuable topsoil, while sedimentation reduces the capacity of lakes and streams. In addition, phosphorus moves with the water flow, largely by binding to the suspended soil particles. Gradually phosphorus dissolves into the surface water body. In most prairie ecosystems, phosphorus is considered the key factor in the growth of algae, including toxic blue green algae. Resulting increases in the growth of aquatic plants can impact water quality. Conservation tillage methods, and effective crop residue management, can play a major role in reducing erosion. Properly planned and constructed drainage projects will limit erosion.
- Loss of wetlands due to drainage has a negative effect on water quality. Wetlands can reduce levels of nutrients such as phosphorus and nitrogen by more than 80 per cent. Wetlands also allow water to spread out and slow down which results in more than 90 per cent of sediments being deposited before they reach the tributaries. A reduction in flow velocities will also reduce erosion. Water stored in wetlands may recharge groundwater. Drainage of wetlands and reduction of groundwater recharge can impact water quality.

Non-cultivated lands can be beneficial to the health of the watershed. Conversion of cultivated lands to forages or permanent cover reduces erosion potential. Grassing of waterways and retention of vegetation in riparian areas can reduce flow rates, erosion, and downstream sedimentation.

Water Quality in the Basin

Water is one of the most important resources in the Assiniboine River Basin. Water is used for fishing, recreation, drinking water, irrigation, and livestock watering.

The Assiniboine River watershed originates in Saskatchewan, northwest of Preeceville, and crosses the Manitoba border west of Roblin.

Various acts, policies, regulations, and guidelines are in place to protect, maintain, and/or improve water supply and water quality for the following purposes:

- preservation and protection of water supplies
- protection of public health
- sustainable development of agriculture and other economic activities
- preservation of aesthetic values
- preservation of fish and wildlife
- municipal and domestic water supplies

In general, any substance that may enter a body of water could be a potential pollutant. Primary factors that influence water quality are the nature and total volume of the pollutant. The resulting water quality depends on the quality of the receiving water, its assimilative capacity, level of mixing, rate of water flows, rate of chemical and biological changes during its flow periods, and other specific use requirements. Major sources of pollutants in the Basin include effluents from sewage treatment plants, suspended sediments, and nutrients and pesticides in runoff from agriculture and livestock operations.

Saskatchewan and Manitoba have established specific Surface Water Quality Objectives, which are used to evaluate the suitability of surface water for various uses. Periodic sampling has been done in the Saskatchewan portion of the Basin in the past as part of specific studies on major water bodies such as Fishing Lake, Good Spirit Lake, Whitesand River and Assiniboine River.

Within the Manitoba portion of the Basin, major bodies of water include the Shell River, Big Boggy Creek, and Lake of the Prairies.

Major parameters for assessing the suitability of water for its various uses in the Basin include:

- Bacteria (total and fecal coliforms)
- Total Dissolved Solids

- Sodium
- Calcium
- Magnesium
- Nutrients (Nitrogen and Phosphorus)
- Dissolved Oxygen
- Pesticides
- pH
- Mercury

For example, levels of fecal coliforms in excess of 200 per 100 mL sample would indicate that the water is not acceptable for contact recreation such as swimming. Total dissolved solids levels of more than 1000 mg/L may not be tolerated by all types of livestock. Similarly, sodium and total dissolved solids levels of more than 100 and 700 respectively make the water unsuitable for irrigation. Using available water quality data, a brief analysis of the suitability for various uses is provided in Table 1. For example, Fishing Lake is suitable for recreation but unsuitable for irrigation and livestock watering due to the high total dissolved solids.

TABLE 1
SUITABILITY OF WATER FOR VARIOUS USES

WATER BODIES	RECREATION	IRRIGATION	AQUATIC LIFE	LIVESTOCK WATERING
Good Spirit Lake (1998 data)	✓	✓	✓	✓
Fishing Lake (1994 data)	✓	X	✓	X
Whitesand River (1976 data)	✓	—	✓	—
Assiniboine River (1991 data at Hwy. No. 5 above Kamsack)	✓	✓	✓	✓
Shell River (1991-1993 data)	✓	✓	✓	✓
Big Boggy Creek (1991 - 1993 data)	✓	✓	✓	✓
Lake of the Prairies (1991-1993 data)	✓	✓	✓	✓

✓ = Suitable X = Not suitable ____ = Required data not available

In general, most water quality uses can be achieved within the Manitoba portion of the Basin. Occasional low dissolved oxygen levels in mid-winter may place some fish communities under stress. Most surface water is generally suitable for irrigation, but there is a tendency in some areas for salt concentrations to become slightly elevated.

Phosphorus concentrations in Lake of the Prairies tended to be elevated, particularly during the open water period. During calm periods, algae blooms can develop fairly quickly and diminish the aesthetic appeal of the lake.

Many acts, regulations, and guidelines are in place to protect water quality. These include:

Saskatchewan:

- Water Pollution & Waterworks Regulations
- A Guide to Aquatic Nuisances & Their Control
- Agricultural Operations Act
- Environmental Management and Protection Act
- Guidelines for Establishing and Managing Livestock Operations

Manitoba:

- Manitoba Environment Act
- Manitoba Dangerous Goods Handling and Transportation Act
- Manitoba Surface Water Quality Objectives
- Fish consumption guidelines in Shellmouth Reservoir based upon mercury concentrations

Federal:

- Fisheries Act

Other:

- Prairie Provinces Water Quality Objectives
- Canadian Council of Ministers of the Environment Water Quality Guidelines

Water Quality Trends

Environment Canada has monitored water quality on the Assiniboine River near the interprovincial boundary for the Prairie Provinces Water Board (PPWB) since 1974. Monthly samples have been collected from the river near Kamsack at the Hwy. No. 8 bridge.

Water quality data collected from the Assiniboine River below Kamsack for the period 1981 to 1997 were examined for long-term trends. Trend analysis techniques were run on the data to determine whether water quality conditions have been changing over the past 17 years. If recent water quality data was not available for a certain constituent then long term trends were determined for the period 1974 to 1993.

In addition to the trend analysis tests, time series graphs with trend slope and water quality objective lines were prepared. These graphs were used to identify seasonal changes in the data base, changes in detection limits, and to verify the long-term trend results.

The results of the trend analysis tests and interpretation of the time series graphs from the Assiniboine River are encouraging. The tests determined that:

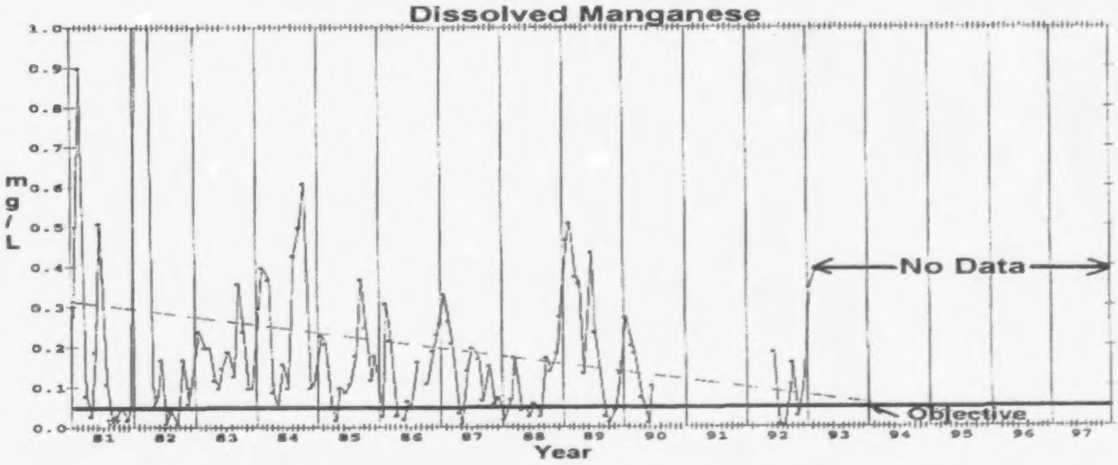
- There was no constituent that showed a significant long-term increasing trend.
- Levels of 2,4,5-T and 2,4-D appeared to be increasing, according to trend test results, but further investigation determined that these trends were likely a result of a change in the analytical detection limit.
- Long-term decreasing trends were determined in nickel (total), fecal coliforms, and in alpha BHC (an isomer of hexachlorocyclohexane). Two formulations have been sold Technical HCH and Lindane).
- It appeared there were long-term trends for boron, iron, copper, nickel, mercury and lead but further investigation determined that these trends were related to a change in analytical method or detection limit and not a result of a change in water quality conditions at the site.

A summary of results and variables of potential concern is shown in the table below.

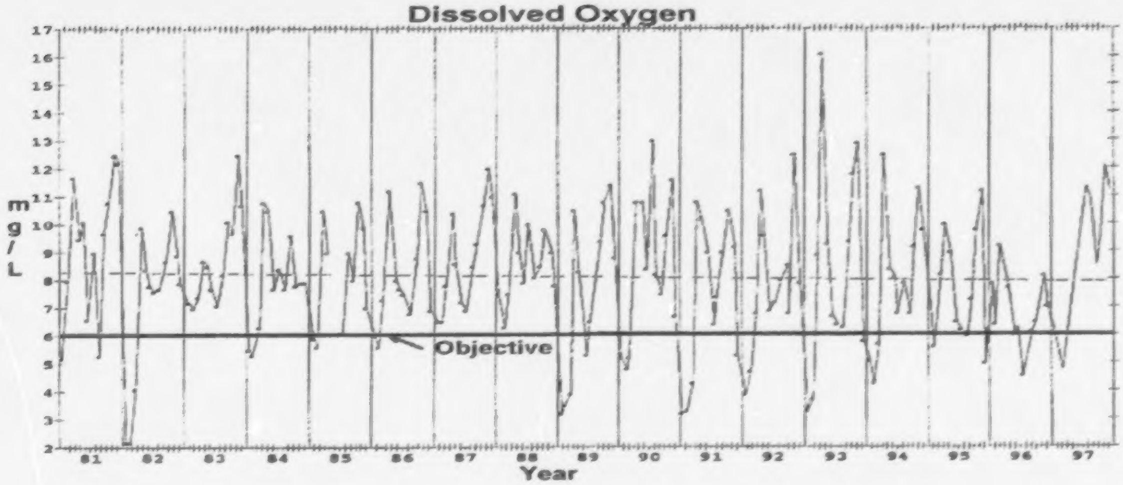
WATER QUALITY VARIABLES	TRENDS	MANAGEMENT IMPLICATIONS
DISSOLVED OXYGEN	None	PC/ above objective
PHOSPHORUS (TOTAL)	None	PC/ above objective
alpha - BHC	Decrease	NC/ no objective
MANGANESE (DISSOLVED)	None	PC/ above objective
NICKEL (TOTAL)	Decrease	NC/ below objective
FECAL COLIFORMS	Decrease	NC/ below objective
2,4,5 - T	None	NC/ below objective
2,4 - D	None	NC/ below objective
No. of Increasing Trends	0	
No. of Decreasing Trends	3	
NC - Not a concern	PC - A potential concern	

A review of the detailed data, a study of exceedances to the PPWB Water Quality Objectives and trend analysis were used to determine variables that may affect downstream uses in the basin. Variables and concerns are as follows:

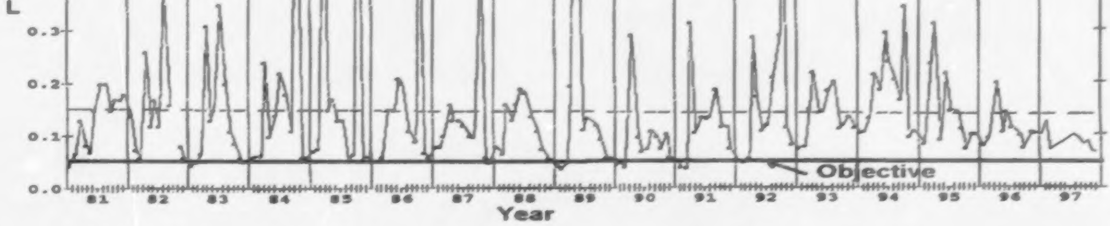
- Dissolved manganese, which has decreased, but not significantly over time, is at levels in the river that exceed the PPWB objective (0.05 mg/L) established to prevent the staining of laundry during domestic use.



- Dissolved oxygen, which must be maintained at a level above the PPWB objective (6 mg/L) to protect cold water fish, has not significantly decreased over the years. Dissolved oxygen has, however periodically dropped below this PPWB objective and is therefore cause for concern at certain times.



- Total phosphorus has not significantly increased over the last 17 years but periodically exceeds the PPWB objective of 0.05 mg/L for the Assiniboine River. This objective was developed to prevent the abundance of algae and aquatic weed growth in flowing streams.



These three constituents, being monitored are at levels of potential concern to downstream users.

Environment Canada recommends monitoring for these three constituents should be continued in the Assiniboine River to determine long-term trends.

Livestock and Water Quality

Management practices associated with all types of livestock activities will have an impact on groundwater and surface water quality. With the increase in both the number and size of livestock operations within the Basin, sustainable livestock management practices become more critical. Impaired water quality can result from:

- Soil erosion due to overgrazing of pasture.
- Nutrient overloading of streams, water bodies and groundwater through improperly controlled runoff from livestock pens or improper application of manure to the land.
- Riparian area degradation due to overstocking of cattle on stream, lake and slough shorelines.

Consider cattle on pasture with free access to open water (stream or lake). Adopting a managed grazing program in conjunction with an off-stream watering system would benefit the producer, the cattle and the environment by:

- Allowing for more efficient use of pasture. Managed pastures produce more pounds of beef per acre.
- Reducing pasture erosion. Managed pastures introduces the cattle to the pasture for short, intensive grazing periods which eliminates over grazing when proper stocking rates are used and maintains proper vegetative cover for soil protection and enhanced plant regrowth.
- Improving herd health. A remote clean water source for the cattle improves their performance while reducing physical damage to the riparian areas. A healthy riparian area has a greater ability to filter nutrients from runoff that may enter the watercourse. Cattle with limited or no access to open water have reduced exposure to disease transmission.
- Increasing wildlife, fish and plant populations along with more stable banks and shorelines.

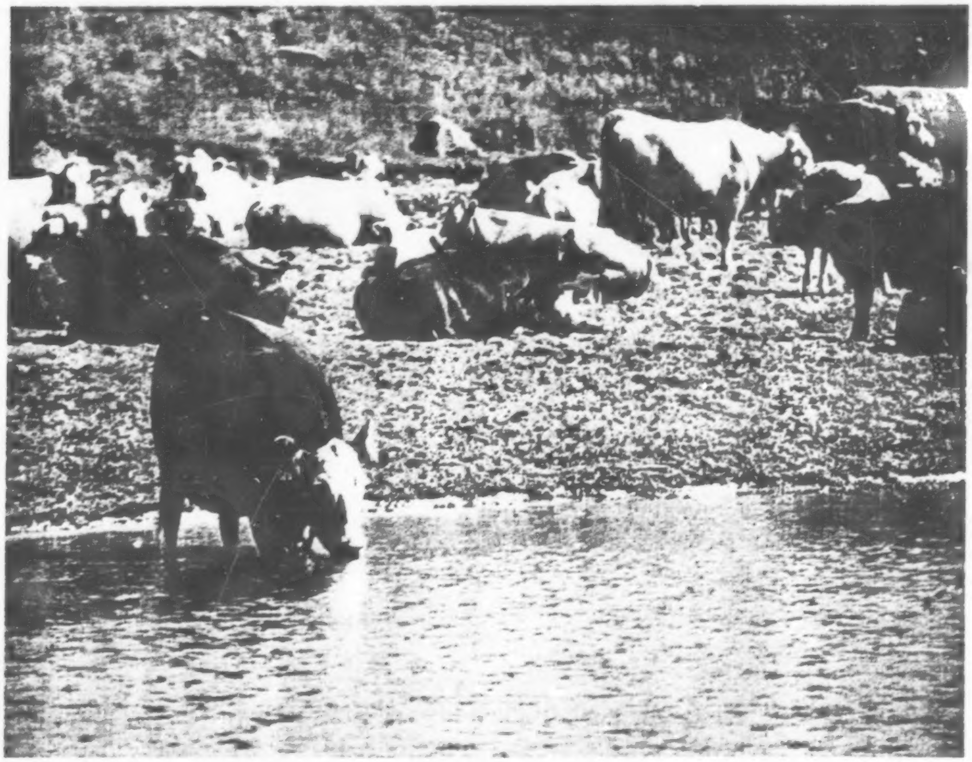
Livestock operations which operate under total confinement, such as cattle feedlots, poultry barns and hog barns, must deal with the storage and hauling of manure, runoff control and dead disposal.

> **Manure storage** - The spreading of manure in winter months on snow covered or frozen ground is not a recommended practice. Confined livestock operations should contain the manure in properly designed and constructed shortages with sufficient capacity to enable timely application of the contents to the land. Both Manitoba and Saskatchewan have legislation regulating earthen manure shortages.

Manure application - Manure is a nutrient rich fertilizer product very suitable for application to crop lands. As with any fertilizer product, the manure should be applied to the land to match the nutrient requirements of the crop being grown. Over-application of the manure not only compromises the environment through a potential increase in runoff and leaching, but also can incur an economic loss to the farmer through lodging and extended days to maturity of the crop. The owner of the land receiving the manure, whether the livestock operator or a neighbor, realizes an economic advantage in having the manure applied at long term sustainable rates.

Runoff control - All livestock operations and cattle facilities in particular, must ensure that runoff from manure areas can not enter watercourses. Holding ponds are commonly used with cattle operations to contain contaminated runoff if the potential for contamination of surface water exists.

Dead disposal - Decaying carcasses can potentially contaminate water sources. Several methods are acceptable when disposing of dead. Rendering is the preferred method but not available at all locations. Burial is acceptable provided the burial site is chosen carefully and the carcasses are covered responsibly.



Herd health can be improved using troughs, instead of surface water sources (pictured above).

Groundwater Protection

Groundwater is a vital resource for residents and communities in the Basin. Often the sole water source for municipal, domestic, agricultural, and industrial needs, groundwater is a valuable resource that must be protected.

Groundwater contaminants are generally grouped into three main categories:

- microorganisms (bacteria, viruses, parasites)
- inorganic chemicals (nitrate, arsenic, metals)
- organic chemicals (solvents, fuels, pesticides)

Groundwater can be contaminated from a number of sources, including fertilizer and pesticide applications, manure storage and spreading, livestock operations, effluent irrigation, landfills, leaking septic tanks and lagoon seepage. An aquifer's susceptibility to contamination varies depending on the permeability of the overlaying materials, land use and depth to the aquifer. Once groundwater is contaminated, it is difficult, expensive and time consuming to clean up. Because a contaminant cannot be easily removed from groundwater supplies, prevention is the only effective approach.

Groundwater can be protected by:

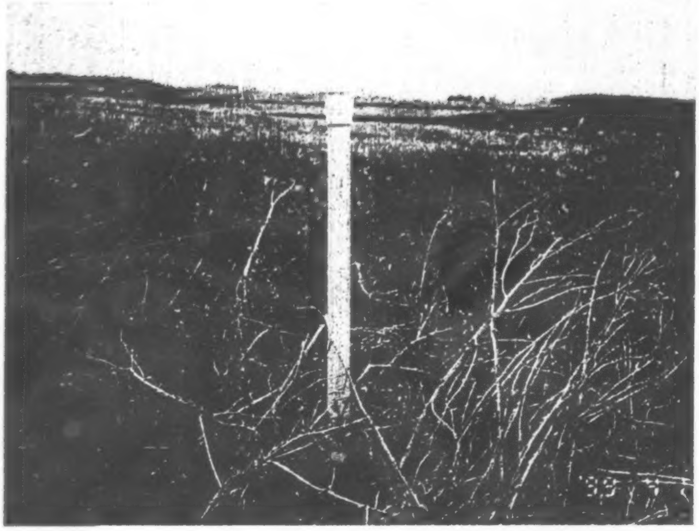
- **Proper well siting** - The location of the well can help to reduce the potential for contamination. A well should be located on properly drained ground avoiding low lying areas where surface water is likely to accumulate around the wellhead. Surface runoff should be diverted away from the well. Wherever possible the well should be located away from potential sources of contaminant such as feedlots, septic systems or landfills.

- **Well Construction** - The most direct route for contaminants to enter groundwater is through the well itself. An improperly constructed well (casing or formation seal) can provide a conduit between the ground surface and the aquifer. Proper well construction should include sufficient grouting between the hole and the casing with an impervious material, watertight well casing, and a well cap that is waterproof and secure. The use of a pitiless adapter to connect the well to the distribution system is necessary to provide a subsurface sanitary connection.

- **Sealing abandoned wells** - When old wells are no longer in use they should be properly decommissioned. When wells are not properly sealed, contaminant can enter the well, impacting the aquifer.

- **Protection from potential contaminant in the recharge area** - Sand and/or gravel upland areas often form aquifer recharge areas. Water can rapidly infiltrate down through sand and gravel into an aquifer providing an efficient aquifer recharge mechanism. This same characteristic also allows potential contaminants to quickly reach an aquifer. Potential sources of contamination such as landfills, livestock operations, lagoons, and chemical storage facilities should be kept away from these areas.

- **Agricultural Practices** - Best management practices have been advocated as a means to reduce non-point contamination of water resources from agriculture. Such practices include avoiding chemical contamination by maintaining a suitable distance from wells during application, practicing proper chemical storage, managing fertilizer applications to reduce nitrate leaching, and minimizing surface runoff.
- **Testing well water** - All wells should be routinely tested to ensure that contamination has not occurred.



Proper well construction is very important to prevent contamination.

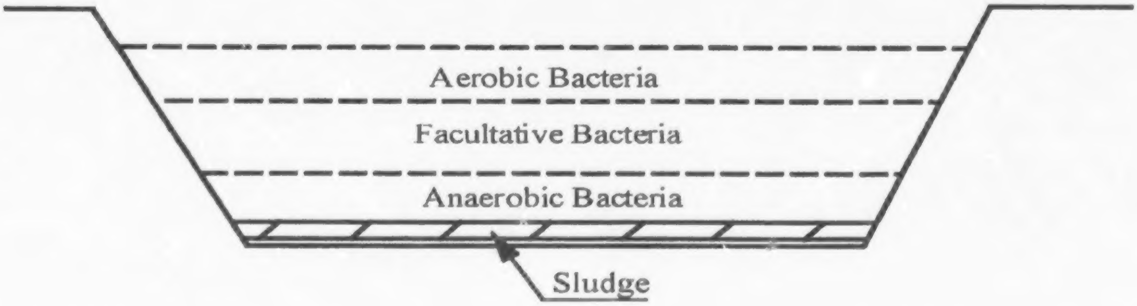
Municipal Lagoons

While large cities have the infrastructure and tax base to install and operate sophisticated sewage treatment plants, most small towns on the Prairies use lagoons as their primary effluent treatment system.

A properly engineered lagoon system is comprised of a primary cell and one or more secondary cells. These cells provide the proper conditions to treat the sewage before discharge.

In the primary cell, heavy organic matter settles out while the lighter organic matter remains suspended. With assistance from the sun and wind, aerobic, anaerobic, and facultative bacteria break down this organic matter and purify the effluent.

Typical Lagoon Operation



Bacterial action is aided in the process by natural forces such as wind, sun, and plant growth. As the effluent quality improves, the cleaner liquid is transferred into the secondary cells, where the purification process continues.

Once the effluent reaches a quality sufficient to meet environmental requirements for disposal, the secondary cells are discharged. For dilution purposes and for continued natural purification, the effluent is normally discharged to a local stream or river during high water flow times. Provincial regulations specify when lagoon systems can be discharged as well as minimum effluent quality to ensure minimal impact on receiving water bodies and fish habitat.

Alternative Effluent Management

Some towns such as Roblin, located in western Manitoba near the Lake of the Prairies, have used alternate management methods for effluent disposal. While lagoons are still used to reduce organic loading through bacterial action, nitrogen and phosphorous are not reduced. It is these nutrients that plants use as fertilizers. Rather than increasing nutrient loading of downstream water bodies, the Town has chosen to operate a number of alternate effluent management methods including effluent irrigation, constructed wetlands, and hybrid poplar plants.

Irrigation

While using effluent from town lagoons for irrigation purposes has been practiced for a number of years, there has always been a problem of either too much liquid during periods of wet weather or too little liquid during periods of drought. For the past 18 years, Roblin has used its effluent to irrigate local crops. Heavier precipitation during the 1990s made proper disposal of effluent by irrigation difficult.

Wetlands

Construction began in the fall of 1998 to install a 16 hectare (40 acre) wetland as part of the effluent management system. Once completed, a large part of the treated effluent from the lagoons will be sent through the wetlands for additional purification and nutrient reduction.

As the pre-treated effluent passes through the wetlands, marsh plants use the nutrients for growth. This reduces the nutrient content of the effluent, resulting in a much improved water quality. The wetlands were engineered to process 136,000 cubic metres (30 million gallons) of effluent yearly with no required discharge during normal to slightly wet years.

Hybrid Poplar Plantation

During the spring of 1999, hybrid poplar trees were planted around the wetlands and lagoon area. The hybrid poplar tree plantation will control any seepage from around the lagoons and wetlands, and can be watered using effluent from the lagoons.

Summary

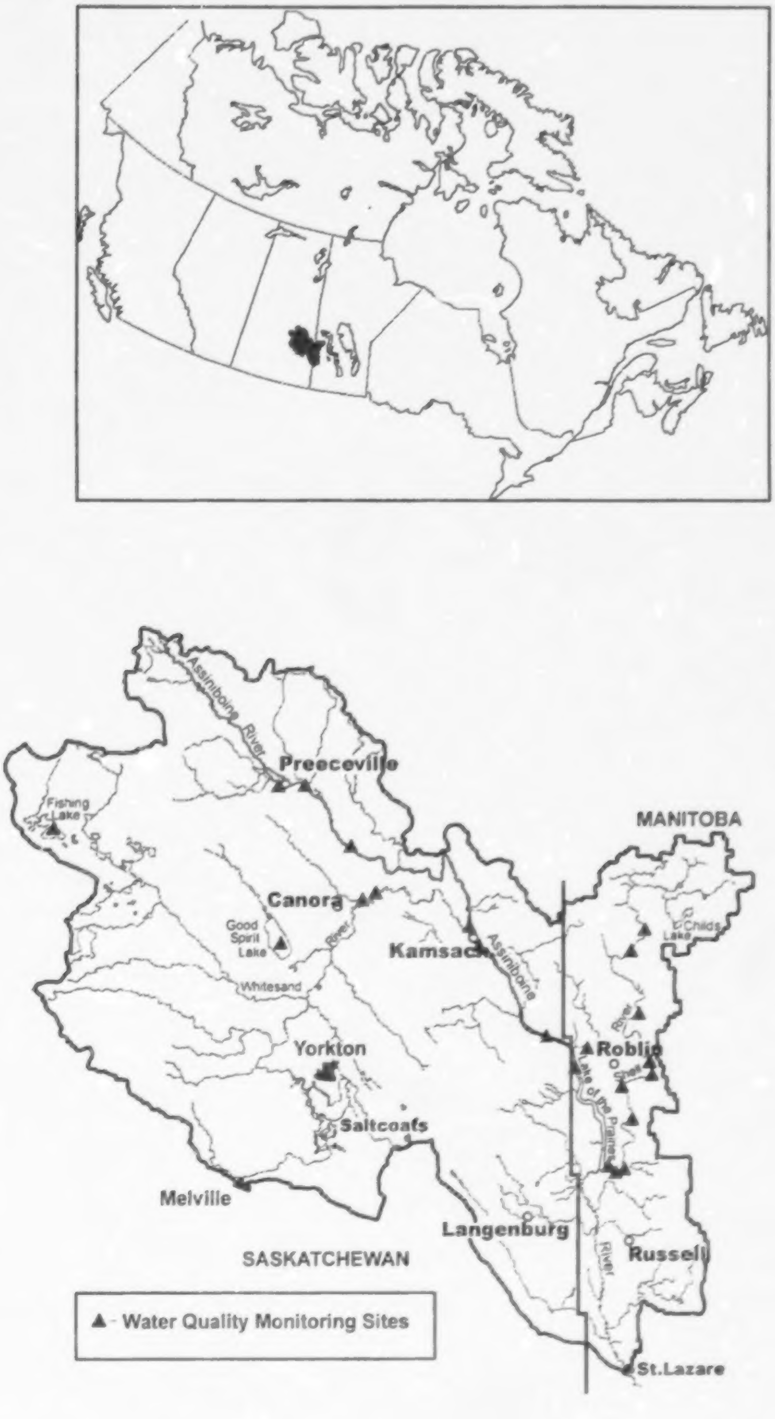
While installing and operating alternate effluent management systems such as wetlands are not suitable for all towns, there are some distinct advantages.

By reducing or eliminating effluent discharges into surface water bodies, nutrient loading of downstream water bodies will be kept to a minimum. This will result in fewer and less severe algae blooms and better water quality. In areas such as the Lake of the Prairies, these factors can have a long term effect on water quality and fish populations, improving potential for economic benefits from tourism.

Since some of the effluent is used for irrigating crops, benefits are realized from increased growth during periods of drought and the additional nutrient content of the liquid.

Engineered wetlands also enhance and increase wildlife habitat and animal life in the area. Many schools are using these wetland areas as an educational tool for their students.

With a multi-pronged approach to effluent disposal, local weather conditions will have a much lower impact on the proper management of the waste disposal system. Versatility is required if any community is to properly manage its wastewater system. It is imperative to work with natural processes to limit effects on the local ecological system. It is always better to take environmental considerations into account at the beginning rather than deal with negative consequences in the future.


Assiniboine River
Preeceville
Fishing Lake
MANITOBA
Canora
Good Spirit Lake
River
Whitesand
Kamsack
Assiniboine
Childs Lake
Yorkton
Roblin
Shell River
Lake of the Prairies
Saltcoats
Melville
Langenburg
Russell
River
SASKATCHEWAN
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Upper Assiniboine River Basin Study Area

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